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EXPERIMENTAL TRANSMITTING AND RECEIVING EQUIPMENT FOR HIGH-SPEED FACSIMILE TRANSMISSION

IV. TRANSMISSION OF THE SIGNALS

by D. KLEIS and M. van TOL.

621.397.242

The transmitting apparatus of a facsimile equipment supplies a voltage which varies in accordance with the blackness of the successively scanned image elements. This "facsimile signal" has a Fourier spectrum beginning at the frequency zero and extending, in the case of the Philips system for high-speed facsimile transmission, to 100 kc/s. In the transmission of the signal to the receiving apparatus, where it has to control a gas-discharge lamp which records the image on a film, there are particularly four stages of importance: amplifying, modulating, reversal and slicing. Modulation on a carrier wave is necessary because the carrier-telephone cables suitable for the transmission do not pass the lowest frequencies of the signal. A carrier of 100 kc/s is used, thus equal to the highest signal frequency; the lower side band is transmitted. At the receiving end no demodulation in the ordinary sense of carrier-telephony is required, and a conventional full-wave rectifier will perform this function satisfactorily. The signal has to be amplified before it is modulated, and in the receiver amplification again takes place in order to modulate an output valve supplying the recording lamp. Alternating voltage amplifiers are used, which, it is true, do not transmit the direct-voltage component of the signal (average blackness of the image, frequency "zero"), but the exact position of all signal levels can be reconstructed by the periodical transmission of impulses with a given level and the use of *C-R* coupling elements with an auxiliary diode. For this principle, known in television, an improved circuit has been applied in our system. A reversal stage permits the recording on the film to be made either positive or negative. The slicer can advantageously be so set that for black-and-white documents, for instance, parts with a reflection coefficient of 60% and more are recorded as white and those with a reflection coefficient of 40% or less as black.

The fundamental principles of the telegraphic transmission of pictures (facsimile telegraphy) may be summarized as follows. A small spot of light is made to traverse narrow contiguous lines on the picture. With the aid of a photocell the varying intensity of the reflected (or transfused) light, which is a measure for the local shades of blackness of the picture, is converted into a fluctuating voltage, the facsimile signal. This signal is transmitted to the receiving station by cable or radio. There, the fluctuating voltage is used to bring about a varying blackness on a light-sensitive material which is recorded line for line in the same way as done with the original document in the transmitting station.

The Philips system for high-speed facsimile transmission [1]) is carried out with a scanning spot of 0.2 mm diameter traversing lines 22 cm long at a rate of 180 lines per second. Thus the scanning rate corresponds to the transmission of the blackness of 200,000 "picture elements" per second. In the receiving station the blackness is recorded on a light-sensitivite material (positive film) with the aid of a gas-discharge lamp the current of which is varied in accordance with the signal received.

The mechanical and optical apparatus used in the transmitter and the receiver respectively for scanning and recording the picture are described in parts II and III of this series of articles. In the present article some details of the electrical circuits employed for the transmission of the signals will be dealt with.

[1]) „Experimental transmitting and receiving equipment for high-speed facsimile transmission", I. General, by H. Rinia, D. Kleis and M. van Tol, Philips Techn. Rev. **10**, 189-195, 1948/49 (No. 7), II. Details of the transmitter, by D. Kleis, F. C. W. Slooff and J. M. Unk, Philips Techn Rev. **10**, 257-264, 1948/49 (No. 9), III. Details of the receiver by F. C. W. Slooff, M. van Tol and J. M. Unk, Philips Techn. Rev. **10**, 265-272, 1948/49 (No. 9), These articles will be referred to as I, II and III.

Transmission links

In *fig. 1* a block diagram is given representing the most important transmission elements that the signal passes through on its way from the photocell in the transmitter to the recording lamp in the receiver. This refers to transmission by a carrier-telephone cable. The transmission elements have mainly the following functions:

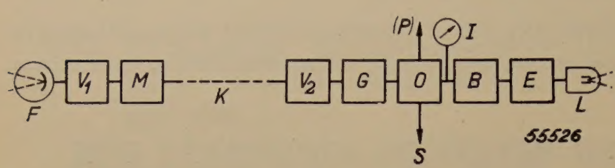

Fig. 1. Diagrammatic representation of the path followed by the facsimile signal from the photocell F at the transmitter to the recording lamp L at the receiver. V_1, V_2 amplifiers; M modulator; K cable; G rectifier; O reversal stage and synchronising separator (S) and, if required, arrangements referred to in article III for punching the films (P); I level meter; B slicer; E output stage.

1) amplification of the signal (amplifier V_1 in the transmitter, V_2 in the receiver);
2) modulation of the signal on a carrier-wave for transmission via the cable (modulator M), and "demodulation" in the receiver (rectifier G);
3) reversal, if desired, of the "polarity" of the signal, for positive or negative reproduction of the original (stage O in the receiver);
4) slicing of the signal if only "black" and "white" have to be reproduced and no half-tones (stage B and the output stage E of the receiver).

In the output stage E the signal is brought to the required level to be able to feed the recording lamp.

We shall not give here any systematic description of all parts of the block diagram in fig. 1, but shall confine ourselves to a more or less fundamental consideration of the manner in which the four above-mentioned functions are performed, beginning with a discussion of the signal to be transmitted.

The facsimile signal

When one line of a normal letter is scanned a voltage, which varies in the manner represented schematically in *fig. 2a* (cf. also the oscillogram of fig. 5 in article II), will be obtained across the resistor through which the current from the photocell in the transmitter is conducted. This signal voltage reaches the level C when scanning white paper having a reflection coefficient of say 85%. It drops to the level B when the scanning spot crosses a black line, for instance of a written or typed letter; the reflection coefficient of the "black" of such a line amounts mostly to 20—25%. At the beginning of each line the scanning spot passes over an aluminium plate the specular reflection of which results in an impulse at the level D corresponding to a reflection coefficient of 110% (see article II). At the end of the line the spot passes over an opening with reflection coefficient zero, so that the voltage drops momentarily to zero (level A).

The signal voltage for black, level B, amounts to approx. 0.2 V and that for white, level C, to approx. 0.7 V (see article II). The overall "amplitude" of the signal, i.e. the distance between the levels A and D, is thus about 0.9 V.

When, instead of a normal document with black lettering on white paper, a document with white lettering on black paper is scanned (e.g. a negative photostat print) then a signal is obtained as represented in fig. 2*b*. There the voltage is mostly at the level B rather than at C. When instead of a letter a photograph with half-tones is scanned then the

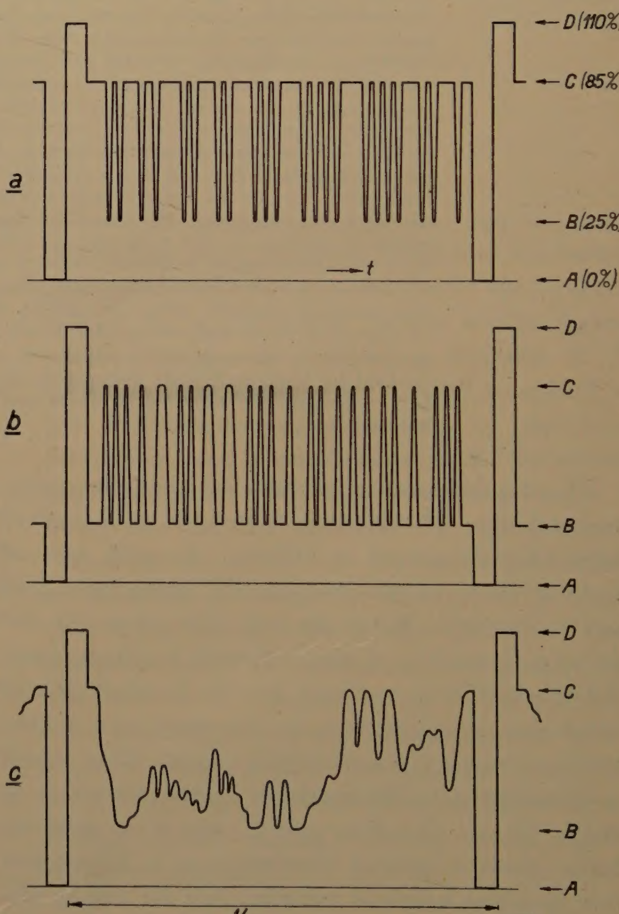

Fig. 2. Wave form of the facsimile signal obtained when scanning one line: *a*) white background with black lettering, *b*) black background with white lettering, *c*) half-tone illustration. On the white parts of the paper the coefficient of reflection may be for instance 85%: level C; on the darkest parts about 25%; level B. Pulses with the fixed levels D and A, corresponding to coefficients of reflection of 110% and 0% respectively, are transmitted with the signal at the beginning and end of each line.

signal will take a form as shown in fig. 2*c*, all levels between *B* and *C* being possible, corresponding to the various shades of grey.

If a Fourier spectrum of the facsimile signal is constructed it will be found to contain frequencies from zero up to 100,000 c/s. The highest frequency occurs when the document has alternating white and black lines 0.2 mm in width perpendicular to the scanning lines. The 200,000 "picture elements" transmitted per second then have alternating levels *C* and *B* answering to a (fundamental) frequency of 100 kc/s. (Actually the signal then also contains harmonics of this fundamental frequency, but these are not essential for the separate reproduction of the lines.) The lowest frequencies occur when the document has uniform grey parts which more or less gradually vary in blackness in a direction perpendicular to the scanning lines. The extreme case is the component with frequency zero (direct-voltage component) answering to the average brightness of the document being transmitted.

Owing to the occurrence of the low frequencies, from zero onwards, these signals differ from most other signals occurring in telecommunication technique.

Amplification of the facsimile signal

The amplifiers in the transmitter and in the receiver must transmit equally well all the frequencies occurring in the signal. This is essential because otherwise, owing to the distortion of the signals, any shade of grey in the documents being transmitted would not always be recorded with the same degree of density.

As regards the high frequencies this requirement does not give rise to any fundamental difficulties. For the very low frequencies, however, in particular for the component of the frequency zero, somewhat exceptional measures have to be taken, since with a normal alternating-voltage amplifier the very low frequencies are greatly attenuated owing to the *C—R* coupling between successive stages, whilst the direct-voltage component is entirely lost; the differences in the average brightness of successive documents and also of parts of one document would not be correctly reproduced in in that case.

In order to explain the remedy applied — which with some modifications has been taken from television technique where the same problem arises — it will be considered what happens to the signals for various documents when passing through a *C-R* coupling element.

We shall consider separately the case of a white document with black lettering and that of a black document with white lettering. Across the input *e-f* of the coupling element drawn in *fig. 3* we get a signal according to fig. 2*a* or fig. 2*b* (in both cases

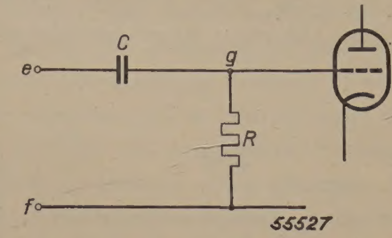

Fig. 3. *C-R* coupling between two stages of a conventional A.C. amplifier.

augmented with a D.C. component originating from the anode direct voltage of the preceding amplifying stage). The corresponding grid potential will also be as shown in figs. 2*a* and 2*b* respectively. Since, however, the blocking capacitor *C* removes the D.C. component between *e* and *f* of the current through the resistor *R*, the mean potential of *g*, taken over a sufficiently long time, will always be equal to the potential of *f*. With respect to this given zero level we therefore get a grid potential varying according to *fig. 4a* in the case of a white document with black lettering and according to fig. 4*b* in the reverse case. If the amplifying valve shown in fig. 3 is the output valve of the receiver then it is clear that in the two cases in question any signal level, for instance level *C*, produces entirely different currents in the recording lamp and is therefore reproduced on the film with different densities.

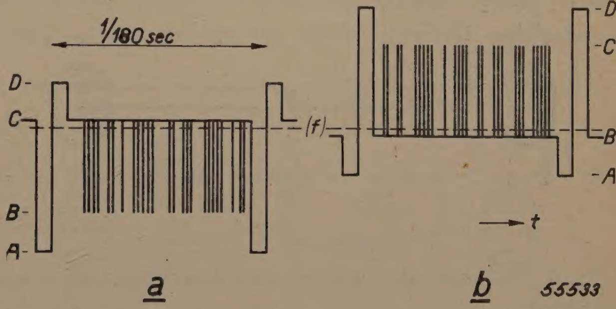

Fig. 4. Variation of the potential at point *g* of fig. 3 (*a*) when a signal according to fig. 2*a* is applied to the input *e-f* and (*b*) with signal shown in fig. 2*b*.

When in the transmitter a black document immediately follows a white one the form of the signal voltage at *g* will be as shown on the left-hand side of *fig. 5*. The time constant *R·C* of the inter-valve circuit determines the rate at which the mean potential of *g* again reaches the potential of *f* after the transition. This change in potential is observed on the film as a gradual decrease of density of the black document.

In our case, therefore, the normal A.C. amplifier mixes things up, because the reproduction of each signal level will be influenced by the average blackness of the preceding picture lines scanned. This way of expressing things is better suited for our purpose than the more usual consideration of the transmitted frequencies from which we started above.

The remedy applied by us to overcome this trouble consists in shunting a diode across the resistor R of the last inter-valve circuit; see *fig. 6*. Thus, no matter whether the signal between e and f follows the lines of fig. 2a or those of fig. 2b the peak potential of g of the signal (level D) will always be substantially equal to the fixed potential at point f; as soon as g becomes positive with respect to f, the diode conducts and in a very short time the capacitor C becomes sufficiently charged and the potential difference between g and f drops to zero. In this way, therefore, the grid of the output valve always has the same potential (namely practically that of the diode-cathode) for the signal peaks with level D, corresponding to the reflection coefficient of 110 %. Further, it is arranged that the amplitude of the signal at the input e-f, i.e. the difference between the levels A and D, has a suitably chosen and constant value for all documents, independently of any gradual changes in the scanning lamp, optical system or photocell of the transmitter or in the amplifying valves, etc. For this purpose a special measuring circuit has been designed to give a direct reading of the said difference on a meter (see I in fig. 1; for reasons stated later, this measuring device is connected prior to stage B and not to the input of stage E). The amplification of the signal received is adjusted by hand until the meter indicates the prescribed amplitude. Thus also level A, corresponding to the fixed reflection coefficient of 0%, is always at a certain grid potential of the output valve and accordingly B (black), C (white) and all intermediate tones are likewise recorded correctly. Consequently all shades of grey in each document are recorded with their proper density.

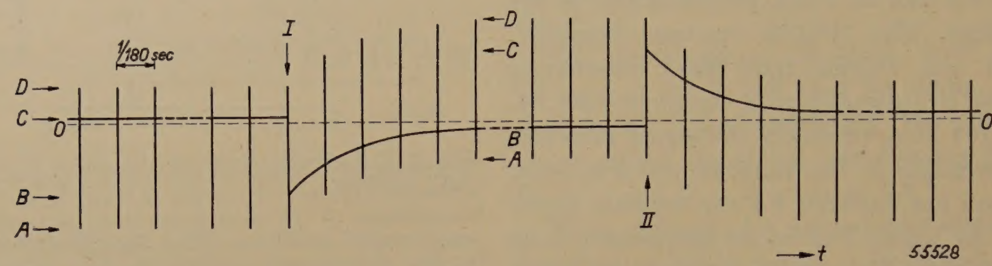

Fig. 5. Variations of the potential at point g in fig. 3 when scanning first a normal white original, then (step I) a black original, followed again by (step II) a white original. The units of time are much shorter than in fig. 4; only the impulses between the successive lines and the background level (first C, then B, and again C) are indicated.

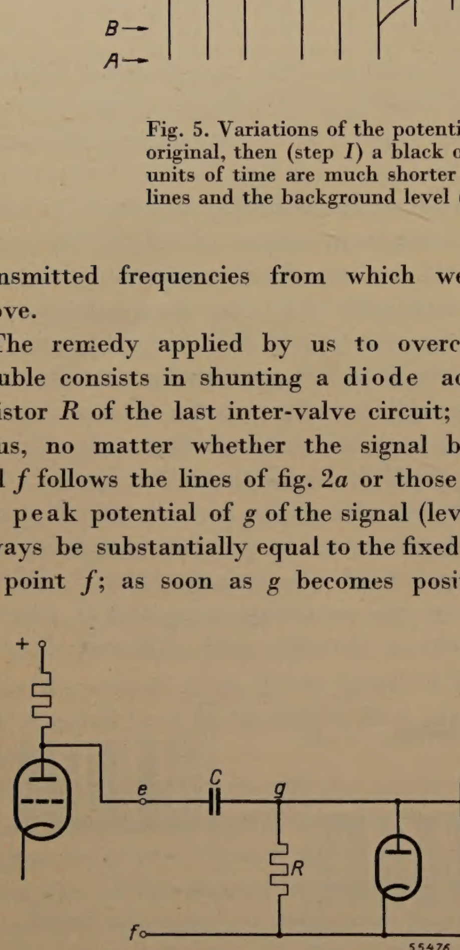

Fig. 6. C-R inter-valve coupling with diode (D.C. restoration circuit).

It is to be seen that this has been made possible by the periodical transmission of the fixed levels A and D, which furnish as it were a scale for the reflection coefficient. It is an important feature that the impulses A and D are obtained by optical means, by reflection from "calibrated" surfaces, and not for instance electronically. Thus the scale is always correct, even when the brightness of the lamp illuminating the scanning spot drops somewhat or when the losses in the optical scanning system increase (see article II).

The essence of the method described is that in the last stage of the receiver the correct mutual position of the signal levels is restored for all documents or parts of documents with the aid of two reference levels A and D and the method of coupling according to fig. 6. In principle, therefore, it is not necessary to maintain the exact position of the signal levels for the intermediate stages of the transmission. Nevertheless the coupling described has also been used in some intermediate stages with the object of improving the conditions under which the amplifying valves work. If a signal, as shown in fig. 5, is applied to the grid of a valve

the overall grid swing is equal to the level between A and D plus the difference between levels B and C (the latter being due to the change from white to black). If, on the other hand, all maxima are lined up by means of the diode circuit, the grid potential only varies between the levels A and D and the swing is thus reduced to about two-thirds of its previous value. Thus the signal can more easily be brought into the linear part of the valve characteristics and a greater amplification can be reached.

D.C. restoration circuit

During the scanning of each line between two impulses D, the diode is non-conducting. In this period of time the capacitor is discharged to a small extent by the resistor R. The potential of g thus shows a small and almost linear increase with time, which is, of course, superimposed upon the signal. The charge, however, is restored by the diode during the short interval of the impulse D (5% of the scanning period of a line). The increase of potential is thus not accumulative and only results in a slight drift of the signal level (cf. figs 2*a* and *b* and *figs 7a* and *b*); this drift is kept small by giving the coupling circuit a large time constant RC.

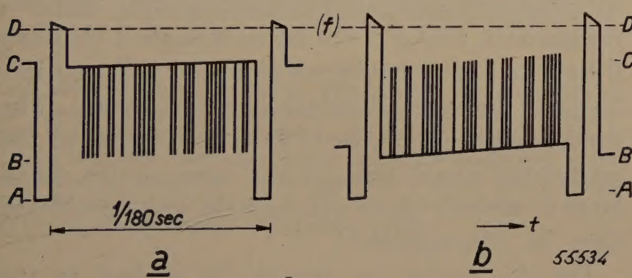

Fig. 7. The effect on the wave form of fig. 4 when the circuit of fig. 6 is used. The potential at g of fig. 6 assumes a fixed value for the maxima (level D) of the signal regardless whether the signal at *e-f* varies according to fig. 2*a* (*a*) or accroding to fig. 2*b* (*b*). The drift due to the discharge of the capacitor through R is superimposed on the potential variation while each line is being scanned. Here the drift is very much exaggerated for the purpose of illustration.

The drift referred to, however, also plays a useful part. Suppose that a signal which has already passed through one or several stages of A.C. amplification (without a diode in the coupling circuits) is applied to the input of the coupling circuit of fig. 6 and that this signal shows a discontinuity like that on the right-hand side of fig. 5 (at a change from a black to a white document). After the discontinuity the potential first drops with an initial slope corresponding to the resultant time constant $(RC)_t$ of the preceding stages. In principle, after the first peak is reached, owing to the tendency of the potential to drop, the diode loses control, with the result that level D departs (at least temporarily) from the fixed potential at which it is desired to be maintained. This falling tendency is counteracted by the aforementioned linear increase of potential occurring during the scanning of each line as a consequence of the discharge current. It can in fact be entirely compensated so that in each peak the diode can perform its conductive function. This compensation is obtained when the time constant RC of the coupling circuit with diode does not exceed [2]) a certain fraction of $(RC)_t$. Considering that RC is required to be as large as possible (see above) and $(RC)_t$ becomes smaller according to the number of coupling circuits without diode employed, all of which contribute to the decline in potential, it is also for this reason of importance to keep the number of amplifying stages without diode in the coupling to a minimum.

A drawback of the simple diode circuit according to fig. 6 is that during the maximum of the signal when the diode is conducting, the anode load is shunted by the much lower resistance of the diode and a portion of the top (D) of the signal is clipped off. This objection is particularly of importance when it is desired to use a rather high value of the anode load in order to obtain large signal voltages with relatively low anode currents.

In order to meet this requirement a modified D.C. restoration circuit has been designed, which is shown in *fig. 8*. It would carry us too far to analyze the working of this circuit; the effect previously mentioned occurs to a much smaller extent, this being attributed to the lower internal resistance

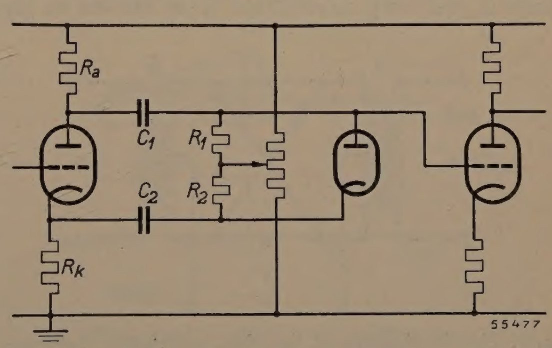

Fig. 8. Modified D.C. restoration circuit. The most important advantage of this circuit is that the flow of current through the diode no longer influences the anode alternating voltage of the preceding amplifier valve. The following conditions must be satisfied:

$$R_a C_1 = R_k C_2,$$
$$R_1 C_1 = R_2 C_2.$$

[2]) This applies for the case where the resistor R is connected directly to the cathode of the diode. The product RC can be considerably increased if a positive voltage is applied in series with R, but such details are beyond the scope of this article.

presented by the preceding stage when the diode is conducting [3]). This circuit has an additional advantage which will be dealt with below.

Modulation and demodulation

The facsimile signal transmitted by the apparatus occupies a frequency band of 100 kc/s. In many countries carrier-cable circuits are available which can transmit a frequency band of this order and over which this facsimile signal can therefore be transmitted. The circuits in the Netherlands, for instance, are designed for fiequencies of 8 to 208 kc/s, thus for a total bandwidth of 200 kc/s [4]).

As the example just mentioned shows, such cable circuits are not suitable for the transmission of low frequencies. Bearing in mind what has been explained above about the amplification of the facsimile signal, one might readily suppose that this property of the cable could easily be compensated by the diode-coupling circuit in the receiver, which restores the correct level proportions when the mean level varies gradually (components with very low frequencies). D.C. restoration, however, is based upon the impulses D and A at the beginning and end of each line, and these impulses, the fundamental frequency of which is 180 c/s, are not transmitted by the cable either. Therefore, for cable transmission the signal is first modulated with a carrier, thus shifting the low Fourier components to a suitable frequency range within the transmitted frequency band of the cable.

For this modulation we apply the principle of the double push-pull connection of valves as employed in carrier-telephony, the best known example of which is the ring modulator [5]) as shown in *fig. 9.*

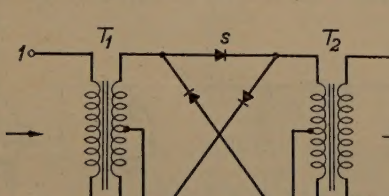

Fig. 9. Circuit diagram of the ring modulator. Between the transformers T_1 and T_2 four selenium rectifying cells are connected as it were in a ring.

[3]) This is the well-known feature of a cathode follower, some resemblance to which is found in the circuit described. In this case, however, the circuit can theoretically give a stage gain greater than unity.

[4]) See for instance G. H. Bast, D. Goedhart and J. F. Schouten, A 48-channel carrier telephony system, I. Choice of the method of modulation, Philips Techn. Rev. 9, 161-170, 1947 (No. 6).

[5]) See for instance F. A. de Groot and P. J. den Haan, Modulators for carrier-telephony, Philips Techn. Rev. 7, 83-91, 1942.

In carrier-telephony technique the carrier, which is of more or less a high frequency, is applied to the terminals *5-6* and the low frequency signal to be transmitted (microphone currents, frequencies q) to terminals *1-2*. The output obtained at terminals *3-4* consists of a voltage alternating with the carrier frequency (p) and varying in amplitude in accordance with the signal voltage. The Fourier spectrum shows that this output voltage contains the sideband frequencies $p+q$ and $p-q$ and some higher modulation products ($3p \pm q$, $p \pm 3q$, etc.); the carrier frequency p itself does not occur, due to the balancing of the circuit with respect to the terminals *5-6*. Neither are there any of the frequencies q at the output [6]). One of the side-bands, for instance the lower one $p-q$, is selected for the transmission after suppression of all other modulation products by means of appropriate filters.

In our case we have to proceed on different lines. With the double push-pull circuit of fig. 9 the amplitude of the modulated carrier is proportional to the difference between the instantaneous and the mean value of the signal voltage, being actually proportional to the absolute value of that difference. For facsimile signals, the D.C. component of which is not transmitted by the transformer at the input *1-2*, this leads to peculiar consequences. Suppose, for instance, that at *1-2* a signal is applied obtained from a document having an average brightness just half-way between B (black) and C (white). The carrier-amplitude for level B at the output of the modulator would then be the same as for signal level C; entirely black and entirely white could not then be distinguished!

For this reason the carrier is applied to the terminals *1-2* and the signal to *5-6*. In this case, too, a voltage fluctuating with the carrier frequency is obtained at the output *3-4*; its amplitude is at any moment proportional to the instantaneous absolute value of the voltage across *5-6*. The signal level D is fixed at a certain potential value, viz. zero, in the manner described above, in a preceding stage. (This comes to the same thing as if an opposed direct voltage equal to the signal voltage for level D were connected in series with the signal.) Since the voltage across *5-6* never changes in polarity but only varies between the value zero (for level D) and a maximum (for the level A), the phenomenon described above can never occur. If, for instance, the signal is as shown in *fig. 10a*, the output will be an alternating voltage according to fig. 10*b*.

The carrier frequency is chosen equal to the

[6]) For details see reference quoted in footnote [5]).

highest frequency in the signal band (q_{max} = 100 kc/s) or if necessary slightly higher or lower. For the transmission the lower side-band p-q is used. *Fig. 11* shows that this side-band lies within the same frequency range as the original Fourier spectrum (q), viz. between 0 and 100 kc/s, but reversed with respect to that spectrum; the

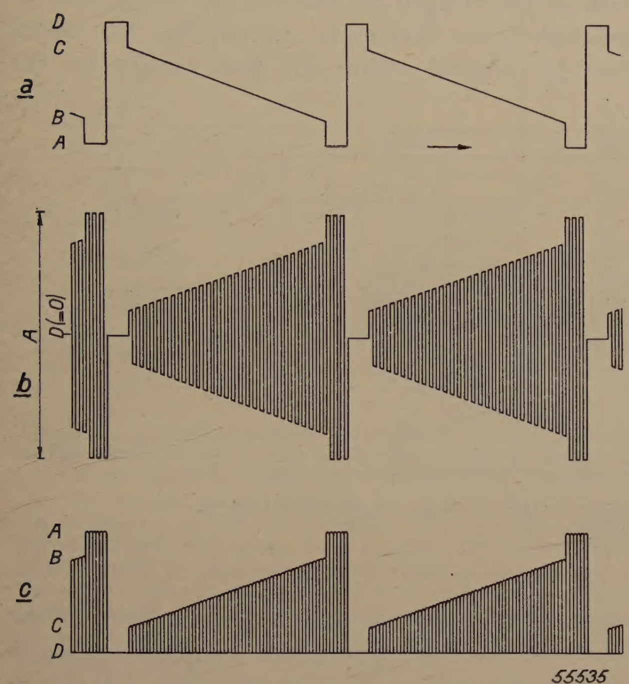

Fig. 10. *a*) Facsimile signal of a document black at one side and white at the other and in between (in the direction of the scanned lines) all intermediate tones. The average brightness lies half-way between the levels *B* and *C*. *b*) Modulated carrier obtained across the output *3-4* of the modulator when the signal (*a*) is applied at the input *5-6* in series with a direct voltage equal and opposed to the signal voltage for level *D*. *c*) Result of a full-wave rectification of (*b*).

low Fourier components of the signal now lie near 100 kc/s and the high ones near 0 kc/s. In the transmission by cable therefore only the highest Fourier components (e.g. from q = 92 to 100 kc/s) are affected, and this does not lead to any appreciable loss of definition in the received record.

This method of modulation is satisfactory for present requirements, namely that a transmission band can be used beginning at the lowest frequencies (thus not for instance for a band of 100-200 kc/s or higher), without having to employ multiple modulation. No trouble is experienced from the original signal, although its frequencies lie within the transmission band, because owing to the balanced circuit of the modulator the signal across *5-6* does not occur at the output. If desired it is also possible here to filter out the upper side-band $p+q$ of the modulated signal, so that the cable, if it can be used for frequencies higher than 100 kc/s, can be kept available for telephony channels located in this frequency range in the normal way.

In order to regain the "low-frequency" signal from the transmitted modulated carrier in the receiver (fig. 10*b* [7])) it could be demodulated according to normal carrier-telephony practice. This is normally carried out by applying it to a modulating circuit according to fig. 9, a voltage with a carrier frequency p being applied to the other input. However, in the case of facsimile transmission a simplification is possible. By merely rectifying the incoming signals with a full-wave rectifier one obtains a voltage as shown in fig. 10*c*. This corresponds practically to the original signal (with the previously mentioned D.C. component) but broken up at twice the carrier frequency $2q$. Remarkably enough this voltage (after the necessary amplification and slicing; see below) can be used directly to modulate the recording lamp: the flickering caused by the pulsating excitation has a frequency such that only small specks would appear having a breadth and distance apart equal to 16.5 μ. As the recording spot itself has a breadth of 33 μ these specks are just fully obliterated, so that no lattice is visible on the record.

If the carrier frequency is slightly higher or lower than 100 kc/s — which in itself is not of much consequence — then the flickering specks are not exactly half the width of the recording spot and they are not fully obliterated. The result is that unless steps are taken to suppress the double carrier frequency (which can actually be done with a very simple filter) some evidence of flickering will be found on the film.

This is the reason why in the method of modulation described the level *D* (the brightest white) is made to correspond to the carrier amplitude zero. In principle it would also be possible to make the carrier amplitude zero for the level *A*

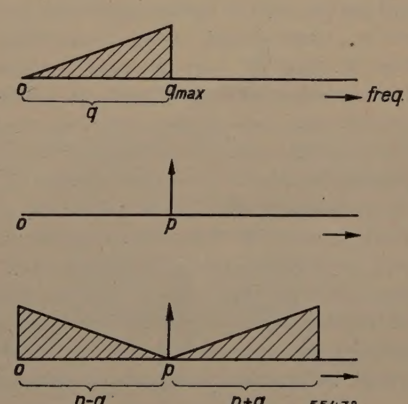

Fig. 11. Frequency allocation of the original facsimile signal (q = 0 up to $q = q_{max}$ = 100 kc/s), of the carrier (p = 100 kc/s), and of the side-bands p-q and $p+q$ obtained by modulation.

[7]) Owing to suppression of the frequencies above 100 kc/s ($p+q$) the voltage wave form transmitted differs slightly from fig. 10*b*, but this deviation (corner of the steep transmissions rounded off) can be ignored here.

(absolutely black) and the maximum for D. In the way chosen, however any stripes can only occur in the black and grey, and not on the white background where they would be more noticeable.

For those accustomed to carrier-telephony practice this direct use of the voltage according to fig. 10*c* may seem surprising, because it is not immediately clear how the original spectrum can be restored from the inverted Fourier spectrum of the voltage according to fig. 10*b*, for there has been no inversion of the frequency band as is the case when demodulating in the normal way. Without going deeper into the matter here we just mention it to illustrate once more that, however useful it may be to consider the frequencies when judging properties of transmission, such considerations do not lead to the simplest insight when the form of the signal becomes a factor to be taken into account.

It may also be worth while to explain the following. If the signal from the photocell is strong enough to be modulated on a carrier directly, without amplification, and if it is then not demodulated until the output stage is reached in the receiver, the abovementioned problem as to how to transmit the "scale" of the facsimile signal can be solved in a much simpler way. Each signal level then corresponds to a certain carrier amplitude right from the beginning and it can easily be arranged for the scale of carrier amplitudes to be faithfully reproduced in a scale of grid voltages controlling the output valve. This is what is done in most systems for slow facsimile transmission; all kinds of methods, partly mechanical and partly electrical, are employed for the modulation. In our case, however, the signal is too weak for direct modulation so that pre-amplification is necessary. Further, in our system the "demodulation" takes place before the output stage is reached, as shown in fig. 1, in order to provide for the slicing without any great complications, a process which will be discussed below. It is for these reasons that the unconventional method of transmitting the limits for black and white had to be adopted; although this method may be somewhat difficult to understand, its practical realization is quite simple.

Reversal and slicing

Fig. 12 is a basic circuit diagram of the amplifying stages in the receiver designated in the block diagram of fig. 1 by items O, B and E.

P_3 is the output valve (EL6), the anode current of which traverses the recording lamp L. A given negative feed-back is provided by a non-bypassed cathode resistor in order to obtain the best possible linear relation between anode current and grid voltage (signal voltage). As maximum current it is desired to use the anode current supplied by the valve at a grid voltage zero with respect to earth [8]); the current is cut off at a grid voltage of -15 V. For the recording lamp to give negative reproduction of the original on the film the valve must in principle pass maximum current for the signal level C (original white) and zero current for the signal level B (original black). This is achieved in the following manner. The signal amplitude from A to D is adjusted to 26 V (using meter I in fig. 1; see above) and with the aid of the diode D_2 the signal peaks are maintained at such a potential that the signal lies within the "grid base" of the valve as shown in *fig. 13b*. The parts of the signal more negative than B fall beyond cut-off and therefore have no effect.

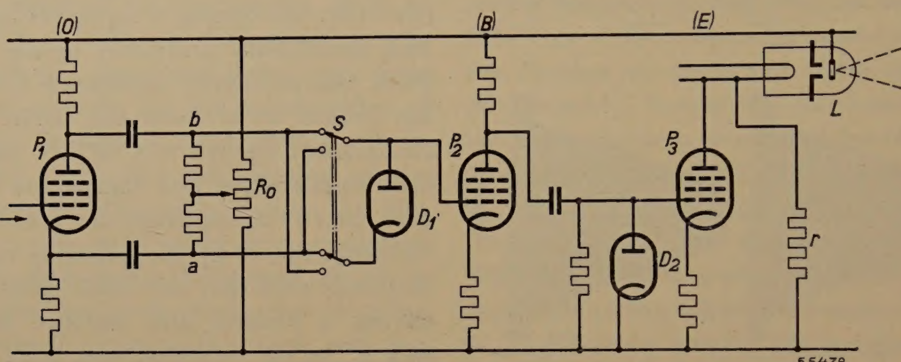

Fig. 12. The last three stages of the transmission, in the receiving apparatus (O, B, E of fig. 1). L is the recording lamp fed by the output valve P_3.

Since with increasing anode current of an amplifying valve the voltage drop across the anode resistor increases, the lower (less positive) the grid voltage of the valve P_2 the more positive is the anode potential of this valve. Therefore, in order to get on the grid of P_3 the signal as sketched in fig. 13*b*, the grid voltage of P_2 is made to vary according to fig. 13*a*: here the signal is reversed. Moreover a further diode D_1 fixes the potential of the "peaks" A and ensures that the signal falls in the grid base of valve P_2 in such a way that the signal levels "below" C (i.e. the pulses D) are cut off. (By the diode D_2 level C is then actually fixed and not level D.)

The combined stages P_2 and P_3 thus effectively confine the signal between the limits B and C.

[8]) The valve is capable of delivering still larger instantaneous currents, but these are not used because the maximum current may persist for long periods of time, as will be seen later.

Actually all that is attained is that the grid base of the output valve available for linear reproduction is utilized to the full. The slicing, however, is of more essential significance when, instead of photographs, originals have to be transmitted which are only black and white.

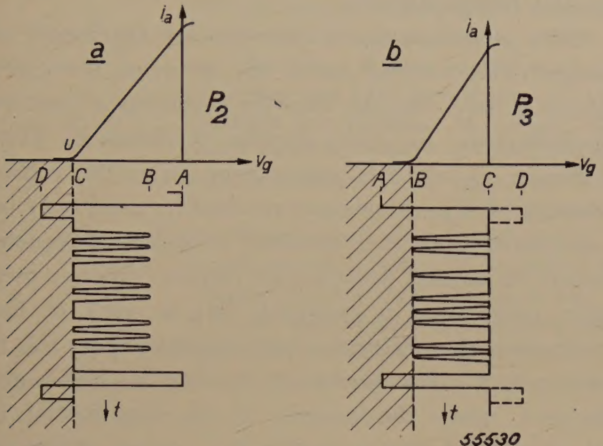

Fig. 13. i_a-v_g characteristics of the fed-back valves P_2 and P_3. *a*) The signal (at the bottom on the left) is applied to the grid base of the amplifier valve P_2 so that the levels "below" C (i.e. the maxima of the impulses D) come to lie below the cut-off point u of the characteristics. This is made possible by maintaining level A at a fixed potential and the amplitude A-D constant. *b*) The position of the signal in the grid base of the output valve P_3 is such that the maximum current flows at the level C (white) which is kept at a fixed potential, and the levels below B (black) lie below the cut-off point. Thus the signal is confined to the limits C and B.

In this case, where it is only a matter of getting the best possible contrast between black and white, the signal is amplified to give an amplitude of say 65 V measured between A and D. It is applied to the grid of the output valve in such a way that the slicing takes place at a signal level B' corresponding for instance to a 40% coefficient of reflection in the original. The maximum current is now already obtained at a signal level C' corresponding to a coefficient of reflection of 60%; see *fig. 14.* The parts of the signal with levels between C' and D are sliced by the preceding stage P_2 in the manner described above. The advantage of this method is, in the first place, that the transitions between black and white are more sharply defined than would be the case with the process according to fig. 13. The impulses corresponding to the lines on the paper traversed by the scanning spot get steeper flanks and thus the blurring caused by the finite diameter of the scanning spot in the transmitter (see article III) is partly compensated. In the second place one now gets a perfectly uniform white background and uniform black letters, whereas the "white" and "black" signal levels B and C used in fig. 13 contain all sorts of noise and random fluctuations such as caused by smudges or spots on the paper or by small irregularities in the focusing of the optical system in the transmitter [9]).

The cut-off levels can be varied by adjusting the gain of the preceding stages and setting the D.C. grid potential of P_2 with the potentiometer R_0 in fig. 12.

In this chapter we have pre-supposed that the output valve had to supply the maximum current at the signal level corresponding to white in the original. On the film we then get a negative reproduction. It is clearly possible that also a positive reproduction can be obtained on the film by "reversing" the signal befoie it reaches the grid base of the output valve, in the manner as shown in fig. 13*a* for the valve P_2: maximum current then has to flow through the recording lamp at the signal level B (or B' if slicing is applied for black and white documents) and zero current at the signal level C (respectively C'). With the circuit of fig. 12 this is very easily done. If the amplification of P_1 is made equal to 1, the coupling circuit with the modified diode connection applied between the valves P_1 and P_2 actually supplies a balanced signal at the output. Thus the potential of point a varies inversely to that of point b, which we have so far been using. The desired reversal of the signal — with the level D given a fixed potential value on the grid of P_2 — is therefore obtained by reversing the diode connections by means of the switch S. By adjusting the said fixed potential value with the aid of R_0 the reversed signal is again applied in the correct manner to the grid base of the valve P_2.

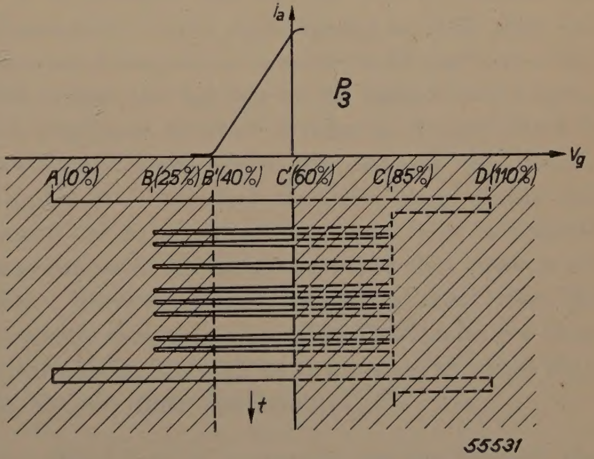

Fig. 14. By strongly amplifying the signal in advance it can be applied to the grid bases of P_2 or P_3 in such a way that these valves act as slicers operating at the levels B' and C' instead of B and C. In this manner black-and-white documents are reproduced with much more contrast and noise and smudges are eliminated.

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[9]) Distortion due to the drift of grid potential in the diode circuit according to fig. 6 is also eliminated by slicing.

Linearity of the reproduction

Finally, the linearity of the complete system has to be considered. The transmitter amplifiers and other links in the chain are substantially linear, that is to say the current supplied by the ouput valve is in a linear relation to the reflection coefficient of the picture elements scanned. In the receiving apparatus, however, certain non-linear elements occur, notably the recording film, the printing paper on which an enlarged positive copy is made, and the recording lamp.

Assume for a moment that the recording lamp had a linear characteristic, that is to say that a linear relation existed between the luminous intensity of the lamp and the current of the output valve. As regards linearity the reproduction through the whole of our system would then be just as good or as bad as could be produced by ordinary photography. It is well known that the non-linearity of the film and that of the printing paper can be made to compensate each other to a considerable degree.

The characteristic of the discharge in mercury and argon, which is used for the recording lamp (see article III), however, is not quite linear. By introducing the resistor r in fig. 12 a small standing current is allowed to flow through the lamp and in this way the curvature of the characteristic can be utilized to improve upon the abovementioned compensation.

This procedure is, of course, only applicable to negative recording and if the inversion described above is used, thereby directly obtaining a positive reproduction, no compensation is obtained. This, however, is of little importance since the reproduction of a positive copy on the film need only be considered when it is intended to make subsequent prints on normal photostat paper (giving a positive print from a positive), but in view of the very steep characteristics of photostat papers this is only possible for documents having no half-tones anyhow, where the linearity of the reproduction is of no account and, owing to the process of slicing described, we even intentionally depart from linear circuit conditions.

ON THE ILLUMINATION OF TRAFFIC TUNNELS

by A. M. KRUITHOF.

628.971.8:535.241.46

A traffic tunnel, for instance one under a river, cannot be illuminated in a practicable manner to the same level of brightness as exists outside in full daylight. An example of such a tunnel will be dealt with to demonstrate the trouble experienced by the driver of a motor vehicle passing through the tunnel, due to the great change in the level of brightness. The nature of these troubles can be considered from the point of view of brightness adaptation and from that of glare. It appears that the data regarding adaptation to brightness are inadequate to provide a basis upon which anything definite can be concluded about the quality of vision. Various performances of the eye, i.a. contrast sensitivity, are reduced by the glare. Data available in the literature on the subject give no satisfactory explanation of the difficulties. Here the results are discussed of a laboratory experiment carried out to investigate the change in contrast sensitivity when approaching and entering a tunnel. The conditions assumed in the case of the tunnel chosen as an example resemble those existing in the tunnel under the river Meuse at Rotterdam. If in the light of these investigations the visual conditions of such a tunnel are to be further improved, this would be possible by raising the brightness in the entrance of the tunnel, which in practice can be done by tempering the daylight just outside the entrance.

Introduction

In modern town planning it has often been found necessary to build a tunnel under a river passing through the town. In the execution of such a project one is faced with a number of problems, one of which is the question how such a tunnel should be illuminated to meet the conditions of safety for fast-moving traffic.

To illuminate the traffic tunnel so intensely as to give inside it the same level of brightness as exists in the daytime on a thoroughfare outside is technically almost impossible and certainly not justified economically. It cannot therefore be avoided that inside such a tunnel the brightness is on a lower level than outside and it takes some time for one's eyes to get adapted to the lower level of brightness. Pedestrians do not as a rule experience any difficulty, for when they descend by escalators or enter the tunnel in any other way there is usually time enough for the eye to adapt itself sufficiently to the changed conditions to be able to distinguish the objects and pass through the tunnel without any trouble. For a motorist, however, travelling at a speed of say 35-40 miles per hour, the time in which the eye has to become adapted to the transition is so short that unless special measures are taken traffic is apt to be seriously endangered.

In this article we shall first try to picture the troubles arising for the motorist when passing through a tunnel under certain conditions taken here as an example.

We shall then investigate further the physiological phenomena which in this case may throw some light upon the quality of vision.

These considerations have led to some experiments being carried out in regard to the behaviour of contrast sensitivity under changing conditions, the results of which experiments will be dealt with at the end of the article.

Example of a traffic tunnel

Let us assume that we have to do with a tunnel for fast traffic about 1 kilometre in length and with separate tubes for each direction of traffic say 7 metres wide and 4 metres high; this width is sufficient to allow of one motorist overtaking another.

It is assumed that for the first 100 metres the illumination inside each tunnel is such that the horizontal brightness amounts to 65 c/m^2; after this 100 metres the lighting of the tunnel itself begins, the brightness of which is taken as 3 c/m^2, which is maintained right up to the exit of the tunnel. Further it is assumed that the lamps inside the tunnel are so arranged that there is no noticeable unevenness in the brightness and that there is no glare. Moreover it is taken for granted that the motorists maintain a speed of 35-40 miles per hour when passing through such a tunnel and that they do not use their headlamps.

The visual field of a motorist passing through the tunnel

When travelling at 35-40 miles per hour on a normal motor road most drivers direct their gaze on a point about 200 metres ahead. During a short interval this distance may be reduced to say 100 metres. If the eye is dropped to a still shorter

distance the road appears to slip past at such a great speed as to be troublesome and very fatiguing for the observer.

When approaching a tunnel along an open road the driver will usually have a field of vision with high level of brightness, varying of course considerably according to the weather and the state of the road surface. On a sunny day when snow is lying on the ground the level of brightness may be as much as 3×10^4 c/m², whereas on a dark rainy day it may be no more than 10^2 to 10^3 c/m².

For the greater part of the driver's field of vision this high level of brightness is maintained up to a few moments before he enters the tunnel, when he very soon finds himself inside where the brightness is at first 65 c/m² and a moment later only 3 c/m².

The question now is whether the human eye is capable of adapting itself to this low level of brightness within the time available. Upon leaving the tunnel, on the other hand, the eye is called upon to adapt itself rather suddenly from a low to a high level of brightness.

Various aspects from which vision in the tunnel is to be judged

The physiological processes taking place in the eye when entering and leaving the tunnel might be regarded as a form of *adaptation to brightness*.

Coming from very bright surroundings the motorist finds himself rather suddenly in a very much less bright environment. What he then experiences bears a certain resemblence to what takes place when one suddenly steps out of a brightly lighted room into complete darkness, or when the lights are suddenly extinguished in a room, with this difference, however, that in the case of the tunnel there is not absolute darkness because, as we have assumed, there is still anyhow a brigthness of 3 c/m².

When using the expression "adaptation of the eye" it implies more or less that it is here a matter of phenomena to which the eye is subject in its entirety. We must not overlook the fact, however, that already when approaching the tunnel the retina is in an exceptional state as regards the distribution of light, since some hundreds of metres before the tunnel entrance is reached the driver will be casting his eyes ahead to see whether there are any obstacles in the tunnel. He will keep his gaze fixed on the tunnel entrance and as a consequence the centre of his field of vision will be formed by an ever-expanding field of low brightness.

The driver's attempts to distinguish details in the field considered will be hampered by the high level of brightness of the rest of the visual field formed by the wall round the tunnel entrance, the part of the sky visible above it, and the road surface between the driver and the tunnel. This high level of brightness will result in *glare* and affect the vision in the central field. For this reason the physiological process taking place in the eye is in the second place to be regarded as a *blinding process*, at least when entering the tunnel.

Thus, while approaching the tunnel entrance, the motorist suffers from glare from the environs of the entrance, but when a moment later he enters the tunnel the high level of brightness has entirely disappeared, though he will still be troubled from its *after-effects*. So long as there is still the high level of brightness one speaks of a *simultaneous* glare, but when it has disappeared one speaks of *successive* glare [1]).

At the transition from the entrance lighting to the lighting inside the tunnel the same processes take place as when entering the tunnel, though at lower levels of brightness.

Both aspects of the problem, adaptation and blinding, will be investigated further in this article.

Before a motorist leaves the tunnel he already has a bright field of vision in dark surroundings at some distance from the exit. The dark surroundings tend to concentrate attention on the bright visual field and favourably affect the observation. Moreover, the fact that the bright visual field gradually becomes larger is also to be regarded as favourable. We shall revert to this later.

Illumination of the tunnel considered from the aspect of adaptation to brightness

The human eye has two kinds of light-sensitive elements, those which are used for *high* levels of brightness and for colours and those with which *low* levels of brightness are observed. When we have been for some time in a brightly illuminated space we see with the elements for high levels of brightness (the cones). When we leave the lighted room and suddenly enter a dark one then the faintest glimmer of light we are capable of observing with these elements corresponds to a brightness of something like 0.1 c/m². This is called the *threshold value of brightness*, with respect to the brightness to which the eye had become adapted in the brightly illuminated surroundings.

When we stay a long time in a dark room this

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1) The various forms of glare have already been discussed at length in this journal, see P. J. Bouma, Philips Techn. Rev. 1, 225-229, 1936.

threshold value brightness drops in about 30 minutes to 6.4×10^{-6} c/m^2 (the graphical representation of this change is called a threshold value curve). The elements for low levels of brighness (the rods) also become gradually sensitive in the dark surroundings, their sensitiveness increasing in all by a factor of 15,000, at which level practically the uttermost limit of light sensitivity (the absolute threshold value) has been reached.

So much for the process of darkness adaptation. The opposite process, of adaptation to light, takes place much quicker. Upon leaving a dark room and entering a brightly illuminated one the eye is usually very soon adapted to the new situation after some blinking.

Both adaptations, to darkness and to light, take place relatively slowly, although the latter is much quicker than the former. The eye, however, has a special property which in the first moments of the change of brightness enables us to neutralize the change at least partly. This property is the power of the pupil of the eye to expand and contract, its diameter varying roughly from 2 to 8 mm according to the brightness observed.

The change in the threshold value as a function of time can be investigated, for a certain degree of brightness to which the eye is adapted, by determining the lowest perceptible brightness at different moments after the high brightness has been removed.

In the example of a tunnel with which we are concerned here the level of brightness assumed in the tunnel itself is still within the range of vision for the cones. Also the time it takes a motorcar to pass through the tunnel is so short that the use of the other elements can be left out of consideration. Consequently we shall only investigate the variation of the threshold value brightness in so far as it is observed with the cones.

Fig. 1 shows such a threshold value curve [2]). It starts from a situation where the eye was adapted to a brightness of 3×10^4 c/m^2 and indicates the change in the threshold value brightness for a natural pupil diameter. With this curve it is possible to ascertain whether we are able to perceive anything when we have to change suddenly from a certain initial brightness to a lower level of brightness, for if the latter lies above the threshold value perception is in principle possible.

In addition to the threshold value curve, in fig. 1 we have indicated by horizontal lines: the brightness to be expected outside the tunnel on a very bright day with snow: $B_1 = 3 \times 10^4$ c/m^2, on a bright day without snow: $B_2 = 2.5 \times 10^3$ c/m^2, on a dark day: $B_3 = 2.5 \times 10^2$ c/m^2; the brightness at the illuminated tunnel entrance: $B_4 = 65$ c/m^2 and that inside the tunnel itself: $B_5 = 3$ c/m^2.

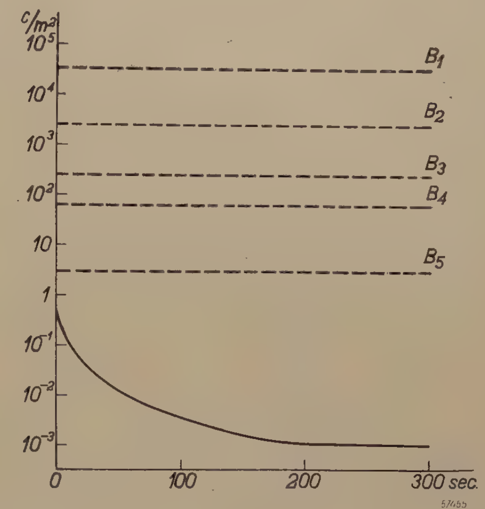


Fig. 1. Threshold value curve for the human eye at an initial brightness of 3×10^4 c/m^2. The curve indicates for this initial brightness the variation of the threshold value brightness as function of time in so far as the eye elements for high brightness are used. The horizontal lines give the degrees of brightness that may be expected in the case of the tunnel considered here as an example: B_1, B_2 and B_3 are the brightnesses outside the tunnel respectively on a sunny day with snow, in clear weather without snow and on a dark day; B_4 is the brightness under the entrance lighting and B_5 that under the normal tunnel lighting.

From this graph it appears that the brightness of the entrance lighting (B_4) lies above the threshold value curve appertaining to the initial brightness in the case of a bright day with snow (B_1). In the transition from B_1 to B_4 (and this is the most unfavourable case that can occur with the tunnel) the eye will therefore most certainly be able to perceive something. Even in the transition from B_1 to B_5 vision is still possible, since the line corresponding to the brightness B_5 likewise lies above the threshold value curve. If the brightness outside the tunnel is B_2 or B_3 it follows a fortiori that the eye is still capable of perception after transition to the brightnesses B_4 and B_5 respectively.

After 60 seconds — the time it takes a motorist to drive through the tunnel — the threshold value brightness has not yet reached its minimum.

It is of importance to note from fig. 1 that after entering the tunnel a motorist is still able to observe things, but it remains the question whether the conditions of vision are adequate for safe traffic.

One might try to obtain an impression of the quality of vision in the tunnel by comparing the

[2]) This curve was calculated according to the theory of Moon and Spencer (J. Opt. Soc. Amer. 35, 45-65, 1945), which represents the phenomena with sufficient accuracy for our purpose.

brightness prevailing there with the threshold value brightness of the motorist's eye.

Suppose that this threshold value brightness is n times lower than the brightness in the tunnel or becomes so many times lower after a certain time. If, either immediately or after some time, n is sufficiently high then one can easily observe any obstacles in the tunnel. The value that this factor n should have depends upon the requirements considered necessary for safe traffic and visual comfort.

For the case of the tunnel considered here as an example, immediately after entering it the ratio of the brightness in the entrance to the threshold value that the eye can perceive is on a very bright day 120, whilst on a dark day the ratio is higher. The question whether this ratio is high enough for adequate visual conditions can only be answered by experimental investigation.

The data available regarding adaptation to brightness are insufficient to allow any conclusion being drawn about the state of vision in the tunnel. We must not, however, confine our considerations to this adaptation as the cause of the change in the threshold value brightness, but must also take into account the behaviour of other physiological properties of the eye which likewise change during the process of adaptation. It is therefore necessary to look more closely into these properties of the eye under the conditions given.

The phenomena on leaving the tunnel thus stand in an entirely different light. Apparently it is the case that during the short stay in the tunnel only a slight adaptation takes place in the motorist's eye, and it is thus understandable that the motorist has no trouble when leaving the tunnel.

Further consideration of the tunnel lighting as a problem of glare

It has already been noted that the phenomena upon entering and passing through the tunnel can also be regarded from the aspect of glare and that we have to differentiate between simultaneous and successive glare.

To be able to study the glare of the various impressions of brightness upon the eye under different conditions it is desirable to express this effect numerically. This is usually done by measuring in how far a certain performance of the eye declines in a particular case of glare.

Thus we are able to measure the decline of contrast sensitivity, of visual acuity, of speed, of perception, etc.

We shall devote attention mainly to contrast sensitivity. This is one of the most important factors governing vision on the road; it is more readily affected by glare than any other factors and easy to measure, whilst much is already known about it. The other factors mostly show a corresponding behaviour.

Contrast sensitivity is defined as B: ΔB, where ΔB is the increase or reduction in brightness just perceptible which can be introduced into a part of the field of vision when the whole of the latter originally had a brightness level B. If somewhere in the field of vision there is an object with a considerably higher brightness than B, for instance a source of light, then that object (or source of light) will give rise to a certain glare manifest in a reduction of the contrast sensitivity.

Measurements of contrast sensitivity in an inner field surrounded by another of high brightness have been carried out by Schuhmacher [3]). These measurements, however, are only of partial use for our purpose, for we have assumed that the brightness of the illuminated tunnel entrance, forming the actual visual field of the motorist before entering the tunnel, amounts to 65 c/m^2, whilst it is further assumed that the surroundings of this field on a sunny day will reach the very high brightness of 3×10^4 c/m^2. Schuhmacher's data do not extend so far as regards the ambient brightness, but they nevertheless go to show that very high contrasts are required for anything to be seen in the given circumstances. From his results it may actually be concluded that with a centre field of 65 c/m^2 the ambient field may certainly not exceed 640 c/m^2 if a contrast sensitivity of 40 is to be reached, and that for the same contrast sensitivity with an ambient field of 6400 c/m^2 the centre field must have 3200 c/m. In this connection it is of importance that the angles of vision from which Schuhmacher took his measurements were of the same order as those which would occur in the case of the tunnel we are considering.

Looking at these figures one would conclude that the tunnel illumination which we have had in mind is quite worthless.

It appears, however, that the lighting of the Meuse tunnel in Rotterdam, which corresponds fairly well to the case we are considering, is indeed reasonably useful, though there is room for some improvement.

Apparently the physiological process with its greatly varying character, whereby the previous situation still has its influence upon the next, cannot be so easily divided into parts, with the result that

[3]) Das Licht 11, 134-135, 1941.

the statically determined data given in literature cannot be applied to our case directly.

Both the considerations of brightness adaptation and those of glare led us, therefore, to take measurements of contrast sensitivity under conditions corresponding to those under which a motorist finds himself when approaching and entering a tunnel.

Contrast sensitivity measurements when approaching and entering the tunnel

A model was constructed and the bright surroundings of the tunnel entrance were imitated by fitting up a large screen of 3 m × 3 m made of tracing paper which could be strongly illuminated from the back. In the centre of this screen, S_1, first a rectangle of 12 cm × 20 cm was cut out and then another of 42 cm × 70 cm, and about 15 cm behind these openings another screen, S_2, with a low brightness was set up. Spots of light, V, 1 and 3 cm in diameter and of high brightness could be projected on this second screen.

We now place side by side in the left-hand column a description of the conditions at the tunnel being imitated and in the right-hand column a description of the manner in which this has been arranged and how the measurements were taken.

A motorist is travelling along an unobstructed road at 35-40 miles per hour on a very bright sunny day. In the distance is the tunnel he has to pass through.

The test person takes up a position 2 metres away from the screen. S_2 is 12 × 20 cm and V has a diameter of 1 cm. The brightness of S_1 averages 6400 c/m^2 and S_2 65 c/m^2.

A certain contrast is adjusted between S_2 and V. The test person is asked to adapt his eye for a few minutes to the high brightness of S_1.

At about 70 metres distance from the tunnel the motorist wants to see whether the entrance is free and so directs his gaze upon it and tries to see into the tunnel.

At a given moment the test person is asked to look at S_2 and to say whether he sees the contrast there. The contrast is changed several times in order to determine the threshold of the contrast sensitivity.

After two seconds the motorist has approached to within 35 metres of the tunnel and tries to see whether there are any obstacles inside it. He will have been directing his gaze continuously upon the tunnel entrance from a distance of 70 metres away.

The test person takes up a position one metre away from the same device. He is again asked to adapt his eye to the high brightness. At a given moment he has to look at S_2 and 2 seconds thereafter the threshold of the contrast sensitivity is again determined.

As the motorist drives on farther the tunnel entrance appears to become larger and any obstacle observed is perceived under an angle increasing in size. After almost two seconds the motorist has reached to within 10 metres of the tunnel entrance.

The screen S_2 is enlarged to 42 × 70 cm and the light spot V is given a diameter of 3 cm. The observer takes up a position 1 metre away from the screen. His field of vision now gives him the same impression as what the motorist gets at a distance of about 10 metres away from the tunnel. The test subject first adapts his eye again to the high brightness. At a certain moment he looks at S_2 and 4 seconds later the threshold of the contrast sensitivity is determined once more.

While travelling the last 10 metres before entering the tunnel the motorist finds his field of vision changes considerably in a very short time. Whereas at first the tunnel with its low brightness occupied a small part of the field of vision, it soon fills almost the whole of it. This is the case at the moment the car enters the tunnel.

The beginning of the test is the same as in the previous paragraph except that 4 seconds after the test person looks at S_2 the brightness of S_1 is brought down to the level of that of S_2. At this moment the test subject starts a stop-watch going. A certain contrast is focused on S_2 and the subject stops his watch as soon as he is able to perceive this contrast. By varying the strength of the contrast the change in contrast sensitivity can be determined as a function of time.

Results of these measurements are represented in the lower half of *fig. 2.* The observations were made with five test subjects, three of whom were less than 30 years of age and two a few years older. The fully-drawn line represents the average contrast sensitivity of these subjects. The spread of the measurements is indicated by the dotted lines. The results of the two older persons show no systematic deviation from those of the other three; neither was this to be expected, since the decline of contrast sensitivity of persons over 30 years of age is only very small during the first few years and the spread of the results is relatively large.

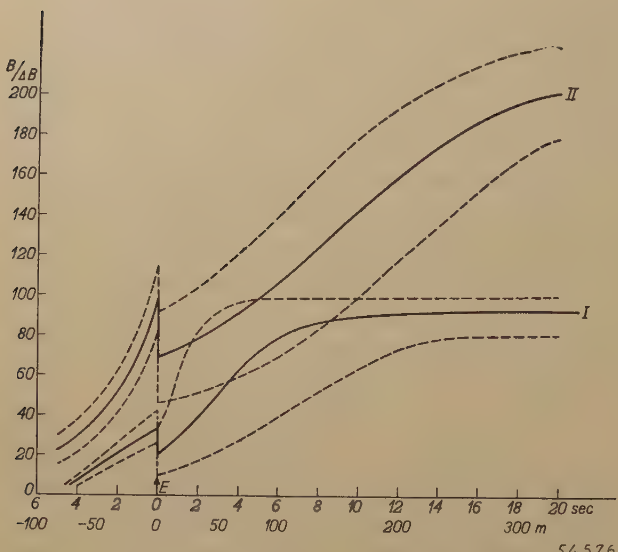


Fig. 2. The results of a laboratory test regarding the change of contrast sensitivity when the brightness and the ambient brightness of the field of vision are changed. The lowermost fully-drawn line indicates the variation of the contrast sensitivity of the eye as it will be according to the test when approaching and entering the tunnel if the brightness of the entrance illumination is 65 c/m² and the ambient brightness 6400 c/m². The uppermost fully-drawn line represents the same variation with an entrance illumination of 600 c/m². In both cases dotted curves are plotted to indicate the spread of the observations taken with 5 test subjects. On the vertical axis the contrast sensitivity $B/\Delta B$ is plotted and on the horizontal axis the distance from the entrance E of the tunnel and the time it takes a car to cover this distance when travelling at a rate of $37^1/_2$ miles per hour.

According to the results of these tests the contrast sensitivity at about 70 metres distance from the tunnel would be about 7, rising to 33 upon approaching the tunnel, then suddenly dropping to 20 and rising again fairly quickly in the tunnel to a maximum value of about 90.

It is to be observed that a contrast sensitivity of 7 (contrast 15%) is not, it is true, so very bad, but when judging the results of these tests it must be borne in mind that they have been carried out by observers possessing a very good contrast sensitivity. In fact it is not the average value that should be considered but rather the least satisfactory results. Further it should be taken into account that during these tests the test subject is much more at ease and thus better able to observe things than he is on the road, and that the obstacle was large and its position known to the test person. Bearing these considerations in mind we must therefore conclude that with the brightnesses assumed the results of our experiments will not always guarantee good vision at the entrance to and inside the tunnel under all circumstances. This led us to investigate in how far the results would be improved if the brightness of the entrance lighting were raised from 65 to 600 c/m². Results obtained from the measurements then taken are represented in the upper half of fig. 2, from which it is to be seen that there is a considerable improvement right at the outset.

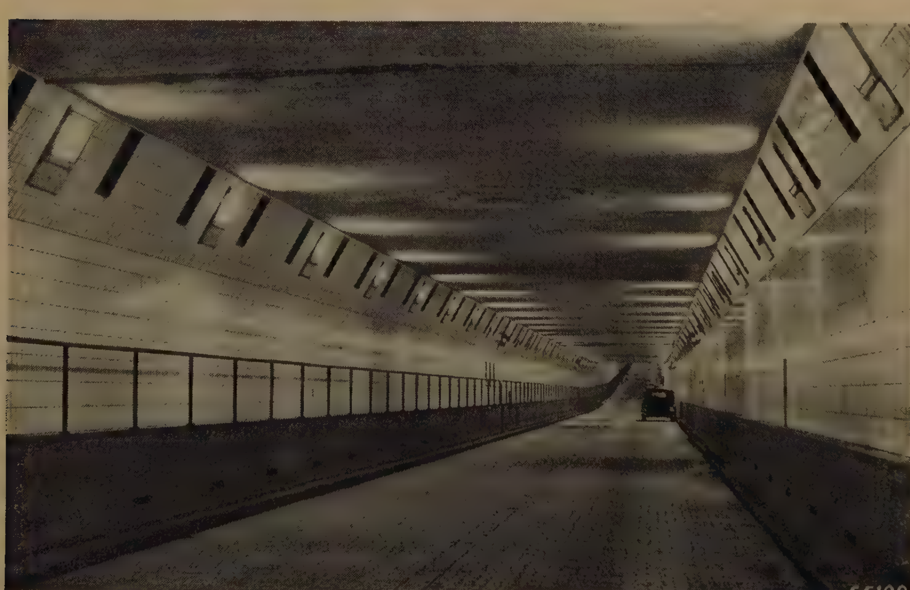


Fig. 3. A view inside the traffic tunnel under the Meuse at Rotterdam, which was opened in 1942. To meet the requirements of fast traffic two tubes were built side by side 1072 metres long, each 7.5 metres wide and 4.2 metres high, with a road width of 6 metres. For the illumination Philips sodium lamps with a flux of 2500 lumen were used, installed in shallow ornaments fitted in niches in the upper half of the tunnel walls slanting forward. The distance between the light points is 6 metres. This illumination gives a brightness inside the tunnel of 3 c/m².

The Meuse tunnel at Rotterdam

It has already been remarked that this, the only large traffic tunnel in the Netherlands, has an illumination closely resembling that of the tunnel upon which we have based our investigations.

A full description of the lighting installation of this tunnel has been given by Van Riemsdijk and Alpherts.

Two photographs of this tunnel (*figs 3* and *4*) are reproduced in this article to give an idea of the effect of the lighting. When we drove through the tunnel by way of a test we found that in sunny weather vision into the tunnel before entering it was not entirely satisfactory, neither when approaching from the southern end nor from the northern end. As soon as one got inside the tunnel it became better, though even then it cannot be said that there was great visual comfort.

Fig. 4. The entrance lighting of the Meuse tunnel at Rotterdam. This entrance or threshold lighting consists of 5 strips of light at intervals of 6 metres in the ceiling. On the right-hand bank of the Meuse, where the tunnel entrance lies NNW, the first light strip is 15 metres from the entrance, whilst on the left-hand bank where the entrance is SE the first strip is 21 metres from the entrance. Each light strip contains 9 fittings, side by side, with mirror reflectors throwing the light opposite to the direction of the traffic. The sodium lamps used have a flux of 10000 lumen. The entrance lighting is divided into two groups so that if necessary on a dull day only half the lighting can be switched on (this was the case at the time this photograph was taken).

The experience that the vision before entering the tunnel was not quite satisfactory is in accordance with the results of the tests represented in fig. 2. Usually under the conditions prevailing here a contrast sensitivity of 40 is considered the minimum required for reasonable visual comfort, and this is not reached along the last 100 metres before entering the tunnel, neither is it attained just inside the entrance.

From fig. 2 it can also be seen what increase in contrast sensitivity may be expected if in the case of the Meuse tunnel the brightness of the entrance illumination were to be raised to 600 c/m². This does not mean to say, however, that we consider it essential to raise the brightness to such a high level, this being a matter that has to be decided according to the requirements made as regards visual comfort.

If the brightness of the entrance illumination has to be considerably raised it is not very well possible to do so by using more powerful lamps. The best solution in this case is to temper the daylight in front of the tunnel entrance, which can be done in various ways. The best known method is to extend the entrance end of the tunnel and to build that extension with a roof in which louvres are let in.

When the plans were being drawn up for the Meuse tunnel consideration was given to such a roof construction letting in the daylight over a length of about 100 metres in front of the actual tunnel, but for aesthetical reasons, among others, this was dispensed with.

DEPOSITION OF SCREENS IN TELEVISION TUBES

Cathode ray tubes for television must be provided with very homogeneous fluorescent screens. Such screens are obtained by deposition of phosphor particles from a dispersing liquid in the following way. After the tube has been filled with a pure liquid to a depth of 2″, a concentrated solution of phosphor mixture is introduced into the tube by pouring it into a rotating glass funnel closed at the end and provided with small holes arranged circumferentially around the stem. The solution flowing down the stem is ejected in a number of tiny streams through the holes and, thus, sprayed evenly over the liquid surface. In this way, the required homogeneous distribution of the phosphor particles in the liquid is obtained.

(Photograph taken at the Dobbs Ferry, N.Y., plant of North American Philips Company, Inc.)

PROJECTION-TELEVISION RECEIVER

IV. THE CIRCUITS FOR DEFLECTING THE ELECTRON BEAM

by J. HAANTJES and F. KERKHOF. 621.397.62:537.533.72

In the Philips projection-television receiver the elctron beam is deflected in a cathode-ray tube magnetically. For this purpose two saw-tooth current generators are needed, one for the horizontal and one for the vertical deflection. With interlaced scanning the frequency of the vertical deflection is equal to the mains frequency (50 or 60 c/s). The frequency of the horizontal deflection depends i.a. upon the number of lines making up a picture and is between about 10,000 and 16,000 c/s. The saw-tooth generators each comprise an oscillator stage and an output stage; the two output stages differ considerably owing to the great difference in frequency at which they operate. In this article first the output stage for the horizontal deflection is described, then that for the vertical deflection, after that the deflection coils and finally the oscillator stages. The output stage for the horizontal deflection contains an "efficiency diode" which ensures a linear saw-tooth shape and also returns to the supply source the energy which at maximum current is accumulated in the magnetic field of the deflection coils. Owing to the fact that this energy is regained, and also due to the use of magnetic material with low losses ("Ferroxcube"), it has been possible to limit the D.C. power consumption of this output stage to 8 W. The output stage for the vertical deflection is characterized by a compensating network connected in series which produces from the saw-tooth input voltage a grid voltage of such a form as to cause the deflection current to assume the right saw-tooth shape, without the output transformer having to have the very high self-inductance which would be required without this network. An additional advantage of the arrangement described is that it allows of a reduction of the direct current consumption, so that in this output stage only 3 W is needed. Apart from an outer layer of iron wire, the deflection coils contain no iron. The two oscillator stages are blocking oscillators supplying a saw-tooth voltage and controlled by the synchronization signals from the transmitter.

Introduction

In all television systems of the present day the scanning in the transmitter and in the receiver is done along horizontal lines which are traversed successively from top to bottom. It is also the common practice nowadays to apply interlacing, that is to say, first a picture is scanned consisting only of lines with odd numbers, then a picture of the intermediate lines of even numbers, then again a picture of odd lines, and so on. (Such a picture consisting of half the number of lines is called a frame; thus a complete picture consists of two frames.) Briefly, the advantage of interlaced scanning lies in the fact that with a given total number of picture lines the brightness of the picture can be increased to a higher level before flickering becomes troublesome [1]). The comparison between interlaced and non-interlaced scanning is explained in *fig. 1.*

In the article just quoted it has also been explained why it is necessary for the frequency of the vertical deflection to be chosen equal to the mains frequency. That is why the television systems in Europe work with 50 frames per second and those in America with 60.

The number of lines per complete picture differs rather considerably in the various countries: the British work with 405 lines, the French with 455,

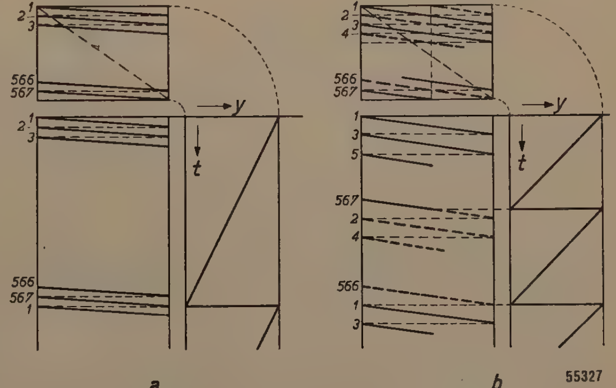


Fig. 1. *a*) Non-interlaced, *b*) interlaced scanning with for instance 567 picture lines. In the case of scanning without interlacing the order in which the lines are scanned is 1, 2, 3, 4 . . . . 566, 567, 1, 2, and so on. With interlaced scanning alternately the odd lines 1, 3, 5, ... 567 and the even lines 2, 4, ... 566 (indicated by broken lines) are scanned. To the right of each of the figures the vertical deflection y is plotted as function of the time t; in *b*) the frequency of the vertical scanning is twice as high as in *a*). The fly-back time of the light spot is assumed to be infinitely short.

[1]) J. van der Mark, Television, Philips Techn. Rev. 1, 321-326, 1936.

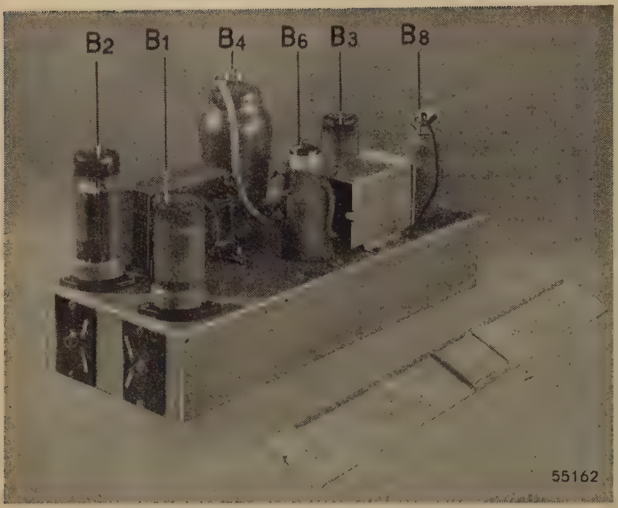
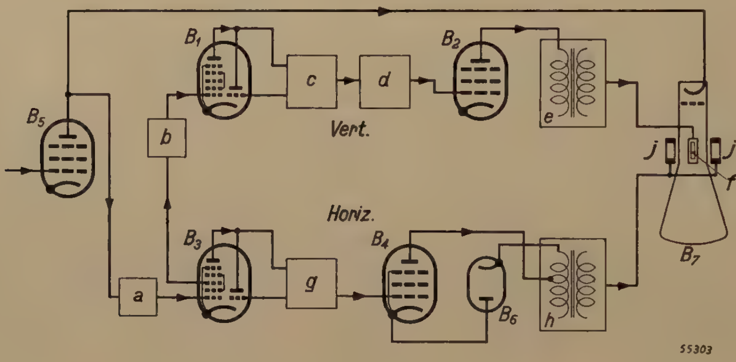


Fig. 2. *Left:* Chassis with synchronizing and deflecting system of the Philips projection-television receiver; *below:* block diagram of the same including the output valve B_5 of the video receiver and the cathode-ray tube B_7.
Horizontal deflection. Oscillator stage: triode part of B_3 with network *g*. Output stage: pentode B_4, diode B_6, transformer *h*, deflection coils *j*.
Vertical deflection. Oscillator stage: triode part of B_1 with network *c*. Output stage: compensating network *d*, pentode B_2, transformer *e*, deflection coils *f*.
Synchronization. From the synchronization signals the networks *a* and *b*, in combination with the heptode parts of B_3 and B_1, derive voltages which synchronize the oscillator stages.
Valves: B_1 and B_3 = heptode-triode ECH 21, B_2 = pentode EBL 21, B_4 = pentode EL 38, B_6 = diode EA 40, B_8 = triode EBC 33 (the function of B_8, which is not referred to further in this article and is omitted in the block diagram, is to suppress the beam current in the cathode-ray tube in the event of a breakdown in the deflecting apparatus, so as to avoid damage to the luminescent screen owing to the light spot remaining stationary or describing only one line).
Supply: 350 V direct voltage, about 15 W (including consumption of the oscillator stages and the synchronization).
Dimensions: Base area 11.5 cm × 29 cm, height 18 cm (roughly 5″ × 12″ × 7″).



the Americans with 525 and the experimental transmitter at Eindhoven with 567.

According to the British system, for instance, in each frame, lasting $^1/_{50}$ second, $202^1/_2$ lines have to be scanned, thus the frequency of the line-scanning in England is $202^1/_2 \times 50 = 10{,}125$ c/s. With the American television system this frequency is $(525/2) \times 60 = 15{,}750$ c/s.

The deflection of the electron beam in a cathode-ray tube, on the screen of which the television picture is scanned, can be brought about with the aid of an electrostatic or a magnetic field. In a previous article [2]) in this series the reasons were summed up which led to magnetic deflection being applied in the projection tube MW 6-2 both for the horizontal and for the vertical direction. Consequently the receiver has to be equipped with two saw-tooth current generators, one working on the mains frequency and the other on a frequency of the order of 10,000 c/s.

These two saw-tooth generators have to run absolutely synchronously and in phase with the corresponding generators in the transmitters scanning the picture, and for this purpose synchronizing signals are transmitted as already described in this journal [3]).

In *fig. 2* a photograph and block diagram are given of the synchronizing and deflecting apparatus used in the Philips projection-television receiver. The cathode-ray tube has two pairs of deflecting coils: *f* for the vertical, *j* for the horizontal deflection. Each pair of coils is fed with a saw-tooth current via a transformer. This current is generated with a saw-tooth voltage derived from a blocking oscillator. The latter consists of a network (*c* and *g* respectively) in combination with the triode part of the valves B_1 and B_3 respectively. The output valve B_5 of the receiver proper supplies on the one hand the output signal direct to the cathode-ray tube, in which this signal modulates the current intensity according to the brightness of the image points, and on the other hand it supplies the synchronizing signals to the heptode parts of B_3 and B_1, which parts are coupled to the triode parts and thus control the relaxation oscillations of the latter.

[2]) J. de Gier. Projection-television receiver, II. The cathode-ray tube, Philips Techn. Rev. 10, 97-104, 1948 (No. 4).

[3]) Television receivers, Philips Techn. Rev. 4, 358-366, 1939.

In the following we shall deal successively with the output stage for the horizontal deflection (from valve B_4 to the coils j, fig. 2,) the output stage for the vertical deflection (from the network d to the coils f), the deflection coils and the two oscillator stages (networks c and g with corresponding triodes). The synchronization will be dealt with in a subsequent article.

The output stage for vertical deflection

There are various methods for generating a saw-tooth current in the deflection coils. One that immediately presents itself, and is in fact sometimes used, is that according to *fig. 3*, in which the coils are coupled via a transformer to the anode circuit of a pentode, to the control grid of which a saw-tooth voltage is applied.

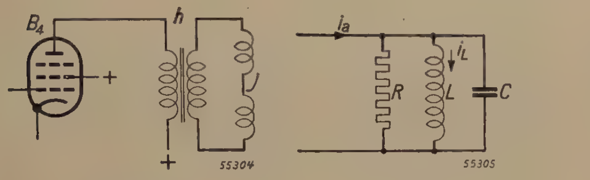


Fig. 3 Fig. 4

Fig. 3. Pair of deflection coils coupled via a transformer to the anode circuit of a pentode. Signification of the letters as in fig. 2.

Fig. 4. Equivalent circuit for fig. 3. L = self-inductance formed by the primary self-inductance of the transformer and the self-inductance of the deflecting coils transformed to the primary side connected in parallel, C = sum of the anode and stray capacitance, R = loss resistance, i_a = anode current, i_L = current in the self-inductance.

For this system we have the equivalent circuit of *fig. 4*. Here the self-inductance L consists of the parallel connection of the self-inductance of the primary transformer coil and the self-inductance of the deflecting coils transformed to the primary side. The capacitance C is the sum of the capacitance of the transformer windings and that of the anode. The resistor R represents the internal resistance of the valve and the losses of the transformer.

The oscillator circuit thus formed with parallel damping is fed with a current i_a the wave form of which is identical with that of the saw-tooth voltage at the grid; i_a thus rises each time linearly from zero to a certain maximum, then flying back to zero (in a decay time which for the sake of simplicity we shall ignore here), and so on. The question now is what form the current i_L will take in the coil, for it is this current that excites the magnetic deflecting field.

Without going into the wave form of i_L in detail, it can be stated that every fly-back of the current i_a gives an impulse to the oscillator circuit (see *fig. 5* and its caption) and if this circuit is less than critically damped the oscillations set up by this will disturb the linearity of the current i_L (fig. 5*d*). It is therefore necessary that the damping should at least have the critical value. More than critical damping is not desired, because then i_L can only slowly follow the fly-back of i_a (fig. 5*f*) and as a consequence the fly-back time of the light spot becomes unnecessarily long. The most favourable condition is the critical damping, for which R must have the value R_{cr} given by

$$R_{cr} = \tfrac{1}{2}\sqrt{\frac{L}{C}}.$$

Since usually R is greater than R_{cr}, the condition of critical damping can be reached by shunting an additional damping resistor across the transformer.

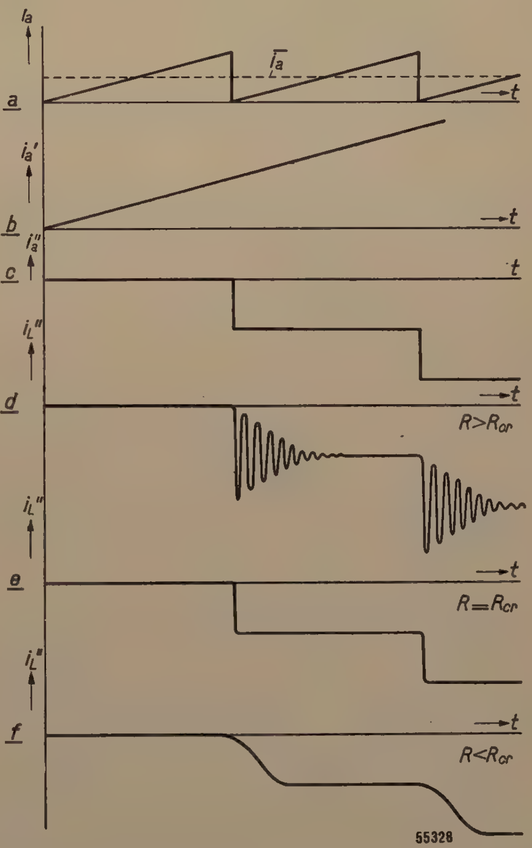


Fig. 5. Wave form of the currents in the diagram of fig. 4 as function of the time t. The saw-tooth anode current i_a (a) can be imagined as being composed of a current i_a' continuously rising in a straight line (b) and a current i_a'' dropping step for step (c). The current i_a' brings about in L a current i_L' (not drawn here) likewise continuously rising in a straight line. The steps in i_a'' excite the L-C circuit, thereby giving rise to a current i_L'' in L which, according to the degree of damping, has the shape shown at d, e or f. At d the damping is too small ($R >$ the critical value R_{cr}), at f it is too large ($R < R_{cr}$), whilst $R = R_{cr}$ at e, which is the most favourable condition. The total current i_L is obtained by adding the current i_L' to i_L''.

With critical damping the decay time of the current i_L lasts well over one oscillation period T_0 of the undamped circuit ($T_0 = 2\pi\sqrt{LC}$). Now in every television system there is a certain time available for the fly-back this varying from 15 to 11% of the time required for the scanning stroke. It is not always easy to choose L and C of such values as to make T_0 shorter than the fly-back time available, because L is more or less fixed by the desired frequency and amplitude of the saw-tooth current, whilst C is limited to a certain minimum by the unavoidable stray capacitances.

Another objection is that in every cycle the magnetic energy accumulated in the deflection coils at the end of the stroke is converted in a resistance into heat, and in the case of the horizontal deflection this happens to the order of 10,000 times per second. This means that a considerable direct-current power has to be supplied to the anode circuit, thus requiring an expensive power rectifier and a high-power pentode.

A slight improvement can be obtained by connecting a capacitor of suitable value in series with the damping resistor, but this is by no means adequate.

It is therefore much more satisfactory to employ a system whereby the energy of the deflection coils is for the greater part **regained**, and we shall now describe such a system.

Recovery of the energy accumulated in the deflection coils

The fact that with the circuit according to fig. 3 the energy in the deflection coils is lost in the form of heat upon each fly-back is actually due to the primary current of the transformer being conducted through a valve (the pentode B_4), in consequence of which this current has a D.C. component (i_a in fig. 5*a*), so that with a supply voltage V_b there is a power dissipation $i_a V_b$. The primary D.C. component is of no consequence for the secondary saw-tooth current — with which we are concerned — and therefore $\bar{i_a}$ may be equal to zero. If this could be realized then i_a would be a purely alternating current and the energy supplied to the deflection coils during one half-cycle would be equal to the energy which these coils return to the supply source during the other half-cycle. **On an average the power consumption would then be zero.**

This condition is reached in the following imaginary experiment (with coils without resistance). Let us consider *fig. 6*, representing the manner in which a saw-tooth current can be generated in a deflection coil L (with capacitance C) by periodically connecting it to a battery via a switch.

So long as the switch is closed the current i_L in the coil (provisionally assumed to be free of losses)

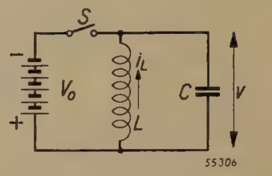


Fig. 6. By closing and opening the switch S periodically at the right moments a saw-tooth current can be generated in the coil with self-inductance L. V_0 = battery voltage. C = self-capacitance, v = voltage across the coil.

increases linearly with the time t in the ratio $di_L/dt = V_0/L$ (V_0 = battery voltage). When at the moment $t = t_1$ the current i_L has reached the value I_L required for the maximum deflection the switch is opened. In the circuit L-C an undamped oscillation is then set up the initial state of which is given by the current I_L in the coil and the voltage $-V_0$ across the capacitor. The current and voltage then change according to sine functions shifted 90° with respect to each other (*fig. 7*) until after slightly more than a half-cycle of this oscillation, at $t = t_2$, the voltage has again become $-V_0$, the

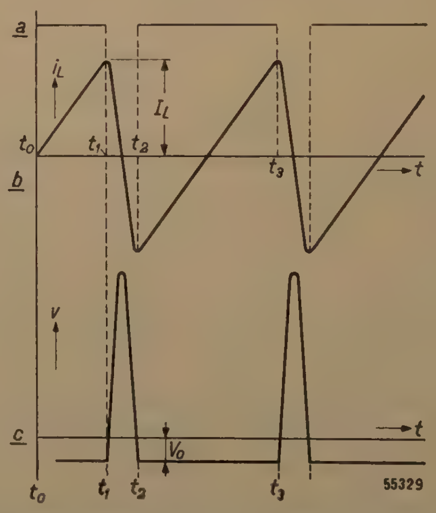


Fig 7. *a*) The straight line represents the closed position of the switch S (fig. 6) and the interruptions the open position. *b*) The wave form of the current i_L in L, *c*) that of the voltage v across L.

current then being $-I_L$. At this moment the switch is again closed. The rate of change of the current is then once more determined by $di_L/dt = V_0/L$ until it reaches the value $+ I_L$ and the switch is again opened, and so on.

In this manner a saw-tooth current is obtained rising linearly and dropping sinusoidally (fig. 7*b*).

In one half-cycle of i_L just as much energy is taken from the voltage source as is supplied to it in the other half-cycle. On an average therefore the battery does not deliver any energy during a cycle, as is only to be expected in a circuit with no energy dissipation. If, however, there are losses in the coil then of course the battery has to supply the corresponding power. The main thing is that with this arrangement the circuit energy is not lost in a damping resistor but returned to the battery (or to the source of energy used instead of it).

As already stated, the flyback covers about half a cycle of the natural oscillation, so that in this respect, as compared with the arrangement of fig. 3, there is a gain of a factor 2 in the duration of the flyback.

A third point in favour of the arrangement of fig. 6 is the fact that when the switch is closed no oscillations can arise during the scanning stroke, so that (at least in the case of a coil without resistance) a purely linear rise of the current is assured.

Efficiency diode

The question now, however, is how to produce a switch which is kept closed (for two directions of current) during the scanning stroke (t_2-t_3, fig. 7) and opened during the flyback (t_1-t_2).

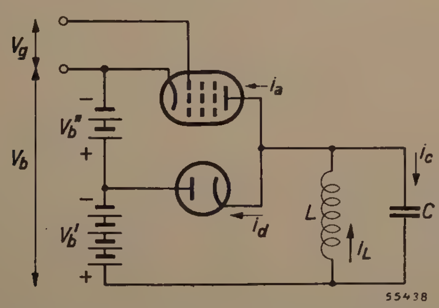


Fig. 8. The switch S (fig. 6) can be formed by means of a pentode and a diode connected in the manner indicated. The diode permits the energy accumulated in the magnetic field of the coil to return to the part V_b' of the battery; the part V_b'', the voltage of which is equal to the anode voltage V_a of the pentode, supplies the energy lost in the pentode.

In *fig. 8* a circuit is shown which approximates the ideal case of fig. 6. As switch we have here for one direction of current a pentode (controlled, as before, by a saw-tooth voltage) and for the other direction a diode, the anode of which is connected to a suitably chosen point of the anode battery. The working of this switch is as follows (see *fig. 9*).

Let us start at a moment when current is passing through the pentode. We assume for the time being that the pentode works in a range of the characteristics where the anode current is blocked during a part of the cycle and rises linearly during the remaining part (fig. 9*e*). For the present the coil resistance is ignored. The voltage v on the coil is then constant at V_b—V_a (V_a = anode voltage of the pentode), the current i_C through the capacitors is zero, whilst the current i_L in the coil is equal to i_a and increases linearly with time. This is maintained until there is a pulse in the saw-tooth grid voltage ($t = t_1$); i_a is then blocked and the circuit formed by the coil and its self-capacitance starts to oscillate (fig. 9) in the same way as indicated in fig. 7.

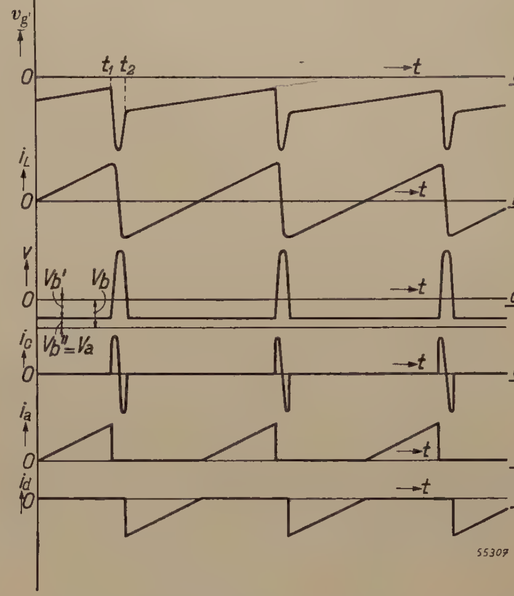


Fig. 9. Voltages and currents in the system according to fig. 8. *a*) voltage v_g on the control grid: negative bias plus saw-tooth voltage plus, during the flyback, negative peak. *b*) current i_L in L. *c*) voltage v across L. *d*) current i_C through C. *e*) anode current i_a of the pentode. *f*) current i_d through the diode.

Meanwhile the anode voltage rises to a high positive value. In order to keep the valve blocked in spite of this, a negative peak is superimposed upon the saw-tooth grid voltage (fig. 9*a*). The manner in which this peak is obtained will be made clear in the description of the oscillator stage.

At $t = t_2$, slightly more than half a cycle of the natural oscillation after t_1, the voltage v across the circuit reaches again the value V_b—V_a (fig. 9*c*). The diode then becomes conducting, since the tapping to which it is connected is so chosen as to have exactly the voltage $V_b'' = V_a$ with respect to the negative pole of the anode battery. The current i_L, which has meanwhile reversed, now flows through the diode, so that energy is returned to the part V_b' of the supply source lying between the tapping and the positive pole. If the internal resistance of the diode is negligible then as long as current is passing through

this diode the voltage $V_b' = V_b - V_a$ across the coil is just as great as was the case when the pentode provided for the passage of the current. In both cases the rate of change of the current will therefore be $\mathrm{d}i_L/\mathrm{d}t = V_b'/L$.

The bias on the control grid of the pentode is adjusted in such a way that as soon as the diode current becomes zero the pentode conducts again, the process then repeating itself. The various currents and voltages in the circuit are represented in fig. 9*a-f*.

Thus we succeed in getting a pure alternating current flowing through the primary of the transformer, as well as through the part V_b' of the battery. In each cycle this part thus receives just as much energy as it supplies. The other part, with the voltage V_b'', supplies the energy lost in the pentode.

The diode has actually a dual function. In the first place it gives the circuit energy an opportunity to return to the supply source, much to the benefit of the efficiency of the circuit (hence the name efficiency diode). In the second place, as long as it is conductive, the diode guarantees a constant voltage across the coil, thus absence of oscillations. According to fig. 9*f* however the interval during which the diode is conducting covers only half of the scanning stroke, but this is easily remedied so as to ensure that the diode continues to be conducting during the whole of the scanning stroke. All that is needed is to adjust the pentode bias in such a way as to cause the pentode to become conducting a little earlier than indicated in fig. 9*e*.

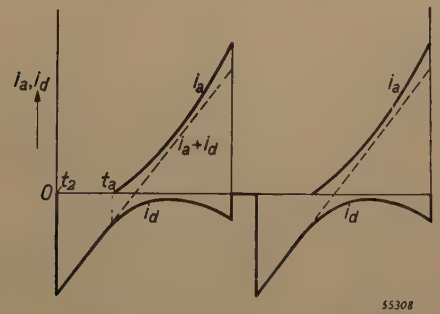


Fig. 10. By causing i_a to start earlier than indicated in fig. 9*e* its wave form will be as represented in this graph. As a consequence of the "excess" of i_a, during the whole of the scan i_d continues to flow and $i_a + i_d$ continues to rise in a straight line.

The situation then is as shown in *fig. 10:* from $t = t_2$ to $t = t_a$ only the diode is conducting, thus $i_L = i_d$ (both negative when taking the current directions indicated in fig. 8 as being positive). At $t = t_a$ current i_a (positive) also begins to flow through the pentode; this current i_a is in excess of what is required for the linear increase of $i_L = i_a$, but this is compensated by i_d, which does not now fall to zero. So long as i_d differs from zero there is a constant voltage V_b' across the coil and consequently linearity of i_L is ensured. Provided i_a is not too small, its exact wave form is immaterial; the pentode characteristics need not by any means be linear (as assumed above), neither is the wave form of v_g of any particular importance. In practice these are advantages that are not to be underestimated.

Nevertheless there is a drawback attaching to this arrangement which makes it unsuitable for practical use. The fact is that in practice one will not use a battery but a rectifier. To get the tapping one then needs a potentiometer formed of resistors the resistance of which must be relatively low if the potential of the tapping is to be sufficiently fixed.

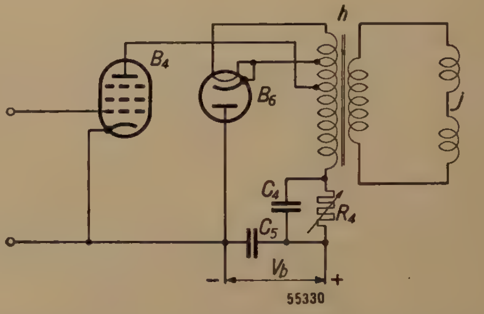


Fig. 11. Variation of the system according to fig. 8. Here there is no longer need to tap the supply voltage (V_b), which in this case is supplied by a rectifier. This system is applied in the Philips projection-television receiver. R_4 = variable resistor for adjusting the picture width. C_4, C_5 = smoothing capacitors. The meaning of the other letters is as indicated in fig. 2.

The power that is lost in these resistors would for the greater part neutralize the gain in efficiency. This could be avoided by connecting two rectifiers in series (the one with the voltage V_b' not then having to supply any power), but this is of course rather cumbersome.

Fig. 11 shows how we have solved this difficulty. The diode is connected between the negative pole of the anode voltage source and the end of the extended primary winding on the transformer. The extension has been so chosen that exactly the voltage V_a is induced in it when the voltage V_b' is lying across the original primary coil. This arrangement is therefore equivalent to that of fig. 8 without the necessity of a tapping on the supply source.

Deviation from linearity due to resistance of the coils

In the foregoing we have all along ignored the resistance of the deflection and transformer coils. Actually these coils do have a certain resistance and

as a consequence when a direct voltage is applied the current i_L will not vary according to a linear but to an exponential function, the rate of change $\mathrm{d}i_L/\mathrm{d}t$ decreasing during the scanning stroke. The relative decline p of $\mathrm{d}i_L/\mathrm{d}t$ during the forward stroke is a measure for the deviation from the straight line.

If we imagine transformer and deflection coils to be replaced by a self-inductance L and a resistance r connected in series, then a simple calculation shows that approximately

$$p = \frac{r}{f_h L},$$

in which f_h represents the frequency of the horizontal deflection.

If, for instance, we allow $p = 0.1$ (thus 10% drop in the velocity of the light spot when scanning one line, which is not yet disturbing) then with $f_h = 15{,}000$ c/s, $r/L < 1500$ sec^{-1}. This condition can be met without much trouble.

Practical execution

The pentode must be able to carry a high positive anode voltage, which during the fly-back may well rise to 4000 V [4]). For this reason the pentode type EL 38 is used, which has a top connection for the anode.

The efficiency diode gets much about the same high anode voltage, but negative, and moreover it must have a low internal resistance. Added to this there is the following difficulty as regards the filament current consumption. The filament cannot be fed from a transformer connected to the mains because this would involve a prohibitive capacitance parallel to the transformer (h, fig. 11) which would increase the fly-back time. That is why the solution has been chosen as already indicated in fig. 11, where an extra winding has been provided on the transformer h for feeding the heater; this means, however, that the power available for the heater is very limited.

Since none of the existing diodes answered all these requirements a new type (EA 40) was developed, the heater of which consumes only 1.4 W and which also satisfies the other requirements.

The transformer coupling the deflection coils to the anode circuit has a core of the non-metallic material "Ferroxcube" [5]), which has a high permeability and very small losses. This also helps to keep the power consumption low.

Connected in series with the primary of the transformer is a variable resistor shunted by a capacitor (fig. 11). In this resistor an adjustable part of the supply voltage V_b is lost, the remaining voltage determining the amplitude of the saw-tooth current and thus the width of the picture on the screen of the cathode-ray tube. (It is to be noted that with the arrangement described the amplitude of the saw-tooth current cannot be controlled by adjusting the amplitude of the saw-tooth voltage applied to the control grid!).

Thanks to the principle of economy described and the low losses, the power for which the output stage and the power pack have to be dimensioned is very low: for the full picture width (about 46 mm) and $f_h \approx 15{,}000$ c/s the current consumption (incl. screen-grid current) is 23 mA at a supply voltage of 350 V. This amounts to a consumption of 8 W, which compares very favourably with the power of about 30 W that would be required without the efficiency diode.

The output stage for vertical deflection

We have seen that the value of r/L of the coils for the horizontal deflection amounts to about 1500 sec^{-1}. With the frequency of the line-scanning (10,000 c/s and higher) these coils constitute a mainly inductive load in the anode circuit with which they are coupled. The pair of coils for the vertical deflection will as a rule have a value of r/L of the same order, but in this case the frequency is so low (50 or 60 c/s) that the coils will mainly act as a resistance; that is to say, at the energy accumulated in the magnetic field when current is at a maximum is small compared with the energy lost in the resistance of the coils during one cycle. There is therefore little sense in trying to recover the field energy in this case.

With this low value of the frequency of the vertical deflection a difficulty arises which does not occur with the line-scanning. This is explained with the aid of the equivalent diagram (*fig. 12*) of

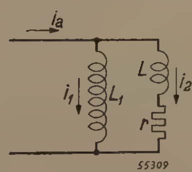


Fig. 12. Equivalent diagram (for low frequencies) for the anode circuit of a pentode feeding the coils for the vertical deflection via a transformer. i_a = anode current, L_1 = self-inductance of the primary transformer coil, L and r = self-inductance and resistance of the deflecting coils transformed to the primary side.

[4]) The manner in which such high voltages arise is explained in the previous article in this series: G. J. Siezen and F. Kerkhof, Projection-television receiver, III. The 25 kV anode voltage supply unit, Philips Techn. Rev. **10**, 125-134, (No. 5), in particular p. 126.

[5]) J. L. Snoek, Non-metallic magnetic material for high frequencies, Philips Techn. Rev. **8**, 353-360, 1946.

the anode circuit of the pentode feeding the coils for vertical deflection via a transformer. L and r represent the self-inductance and the resistance of the deflection coils transformed to the primary side; L_1 is the self-inductance of the primary transformer coil. In view of the low frequency the self-capacitance of the coils may be disregarded here. The parallel circuit is fed with a linear saw-tooth current i_a.

By the same definition as used before we employ a quantity p to indicate in how far the current i_2 in the L-r branch deviates from linearity. By this means we easily deduce the equation

$$\frac{r}{L_1+L} = p\, f_v,$$

where f_v = the frequency of the vertical deflection. With f_v say 50 c/s and p = 0.1, this means that $r/(L_1+L)$ must be less than 5 sec^{-1}. Now, for a good matching to the valve a value of r is required amounting at least to 5000 Ω. Hence $L_1 + L$ must be greater than 1000 H. The value of L being only a few H, the primary self-inductance must be very high and this could only be attained with an expensive transformer.

To overcome this difficulty the following method is sometimes applied. Instead of the transformer a choke is used, the deflection coils in series with a blocking capacitor being connected in parallel to this choke. The choke is given the same value of r/L as that of the deflection coils, so that the wave form of the current is the same in both branches (apart from the direct current, which flows only through the choke) and thus also equal to that of i_a. With this method, however, the deflection coils must have a high impedance for the sake of matching; consequently they must consist of a large number of turns of thin wire. This is not only rather costly but also objectionable from the manufacturing point of view on account of the risk of the wire breaking. Another drawback attaching to high-impedance deflection coils is the high voltage arising across them.

Compensating network

In the system which we employ a transformer is used which has a much lower self-inductance; the great deviation in the linearity of i_L which would result from this is compensated by a network which brings about a certain distortion of the input voltage. This network (d, fig. 2) may consist of two capacitors and a resistor (C_1, C_2, R_1) connected in the manner shown in *fig. 13*. The conditions which have to be met by C_1, C_2 and R_1 in order to give i_L the same wave form as that of the (saw-tooth) input voltage v_1 are deduced below.

To reach the similarity mentioned it is necessary that the Fourier series in which i_L can be developed and that in which v_1 can be developed should differ term for term by only a constant factor in amplitude and have the same phase angle term for term.

A simple calculation shows that for any arbitrary harmonic with the angular frequency ω we must have in the grid circuit

$$V_2' = \frac{1 + j\omega C_1 R_1}{1 + j\omega(C_1 + C_2)R_1} V_1' \quad \ldots \quad (1)$$

and in the anode circuit

$$I_L' = \frac{j\omega L_1}{r + j\omega(L_1 + L)} I_a', \quad \ldots \ldots \quad (2)$$

where V_2', V_1', I_L' and I_a' denote the amplitudes of the harmonics of v_2, v_1, i_L and i_a respectively. Further

$$I_a' = S V_2' \quad \ldots \ldots \ldots \quad (3)$$

where S = slope of the pentode B_2. Eliminating V_2' and I_a' from (1), (2) and (3) we arrive at

$$I_L' = \frac{j\omega L_1 - \omega^2 L_1 C_1 R_1}{j\omega\{L_1 + L + (C_1+C_2)R_1 r\} - \omega^2 (L_1+L)(C_1+C_2)R_1 + r} S V_1', \quad (4a)$$

which may be written as

$$I_L' = \frac{ja\omega - b\omega^2}{jc\omega - d\omega^2 + r} S V_1' \quad \ldots \ldots \quad (4b)$$

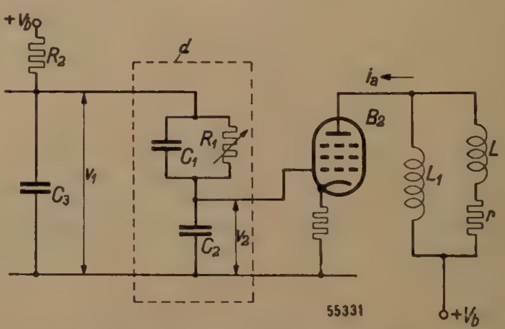


Fig. 13. d = compensating network consisting of the fixed capacitors C_1 and C_2 and the variable resistor R_1. It is connected between the oscillator stage and the output stage for vertical deflection. C_3 and R_2 belong to the oscillator stage; B_2, L_1, L and r (see fig. 12) belong to the output stage.

If the fraction in (4b) were a real quantity and (4b) independent of ω we should have the desired equality of phase and proportionality of amplitude for all harmonics, but this is prevented by the term r in the denominator. Therefore the first condition for attaining our object is that r must be negligible compared with the other terms in the denominator. We shall see presently to what this condition leads, but for the moment we shall assume that r may be omitted. The remaining fraction does then indeed become real and independent of ω when

$$a : c = b : d,$$

that is to say when

$$\frac{L_1}{L_1 + L + (C_1+C_2)R_1 r} = \frac{L_1 C_1 R_1}{(L_1+L)(C_1+C_2)R_1}, \quad (5)$$

or

$$\frac{C_2}{C_1(C_1+C_2)R_1} = \frac{r}{L_1+L} \quad \ldots \ldots \quad (6)$$

C_1, C_2 and R_1 must therefore be chosen of such values as will comply with (6).

Putting $a/c = b/d = 1/q$ then (4b) may be written as

$$I_L' = \frac{ja\omega - b\omega^2}{q(ja\omega - b\omega^2) + r} SV_1'.$$

Thus r becomes all the more negligible as the value of q increases. Now, according to (5)

$$q = \frac{L_1 + L}{L_1}\left(1 + \frac{C_2}{C_1}\right).$$

By choosing

$$C_2 \gg C_1 \quad . \; . \; . \; . \; . \; . \; . \; . \; . \; . \quad (7)$$

we can always make q large enough to allow of r being ignored in the denominator of (4b). This condition $C_2 \gg C_1$ implies that the amplitude of v_1 must be much greater than the desired amplitude of v_2.

Finally we have to bear in mind that the network must not constitute more than a very small load on the oscillator stage, because otherwise the voltage v_1 would not retain its saw-tooth shape. This means that the current taken up by the network must be small compared with the charging current of the capacitor C_3 (fig. 13) in the oscillator stage. This results in another condition having to be met by C_1, C_2 and R_1, which we shall not go into here.

In practice C_1 and C_2 are fixed capacitors and R_1 is a variable resistor so adjusted that the wave form of i_L approaches the ideal as closely as possible; this is in fact managed in a very satisfactory way.

Saving of current

The fact that the distortion of the current in the compensating network is by no means small appears from *fig. 14a*, showing the wave form of

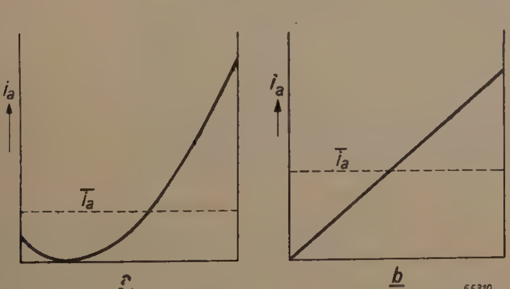


Fig. 14. Anode current i_a during the scanning stroke as function of t, a) when using the compensating network (fig. 13), b) without this network, with the same value of I_L. In the case a) the average value $\bar{i}_a$ may be more than 40% lower than in the case b).

the anode current during the scan; it deviates considerably from the straight line (fig. 14b). In both these graphs, drawn for the same difference between the initial and final values of i_a, thus for the same amplitudes of i_L, also the average value $\bar{i}_a$ of the anode current is indicated: in the case a), where the compensating network is applied, $\bar{i}_a$ is much lower than in the case b). In the case a) $\bar{i}_a$ depends upon the ratio r/L_1 and the calculation shows that it is smallest when

$$\frac{r}{L_1} = 3.45 \, f_V \text{ sec}^{-1};$$

$\bar{i}_a$ is then more than 40% lower than in the case b).

In practice the average anode current consumed amounts to only 6 to 7 mA. With a screen-grid current of 2 mA and a supply voltage of 350 V this means that the power consumption of this output stage is only about 3W.

Practical execution

Fig. 15 gives a complete diagram of the output stage circuit for the vertical deflection.

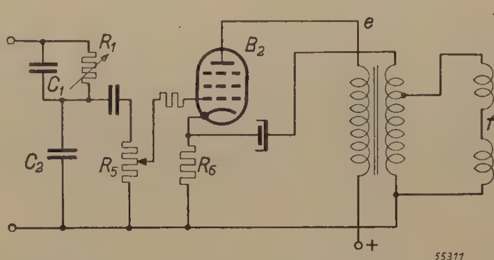


Fig. 15. Complete circuit of the output stage for vertical deflection. C_1-R_1-C_2 = compensating network (fig. 13), R_5 = potentiometer for adjusting the picture height, R_6 = cathode resistor to which feedback is applied. For the rest see the legend in fig. 2.

Across the output of the compensating network an additional potentiometer is shunted (of such a high resistance as to have no noticeable effect upon the network), with which the amplitude of the control grid voltage, thus also the amplitude of the deflection current, can be adjusted for controlling the picture height.

The pentode is of the EBL 21 type.

Just as in the output stage for the horizontal deflection, during the fly-back there is a high positive voltage peak on the anode and while this lasts the anode current has to be kept cut off. This is again brought about by superimposing a negative voltage peak on the grid voltage at the moment in question.

From fig. 15 it is to be seen that negative feedback has been applied; the secondary winding of the output transformer supplies current through a resistor in the cathode lead of the pentode. Negative feedback is a well-known means of reducing non-linear distortion [6]) which may arise from the curvature of the valve characteristic or from the self-inductance L_1 being more or less dependent upon the anode current.

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[6]) B. D. H. Tellegen, Inverse feed-back, Philips Techn. Rev. 2, 289-294, 1937.

The deflection coils

Fig. 16 gives an idea of the shape of the deflection coils. One pair of coils is fitted closely around the neck of the cathode-ray tube whilst the other pair is fitted around the first pair.

It has been deduced above that for the pair of coils for the horizontal deflection r/L must be less than 1500 sec^{-1}. This would easily be complied with if ample use could be made of iron, but this may only be applied around the tube in a strictly rotationally-symmetrical fashion, because the focusing field — which is present also in the deflection coils — causes a disturbing astigmatism of the light spot as soon as there is the least deviation from rotational symmetry. What we have done is to wind a few layers of iron wire around the insulating cylinder enveloping the deflection coils (fig. 16). This appreciably improves the quality of the coils (reduction of r/L).

Fig. 17 shows the cathode-ray tube fitted in the holder with the deflection coils and the focusing coil.

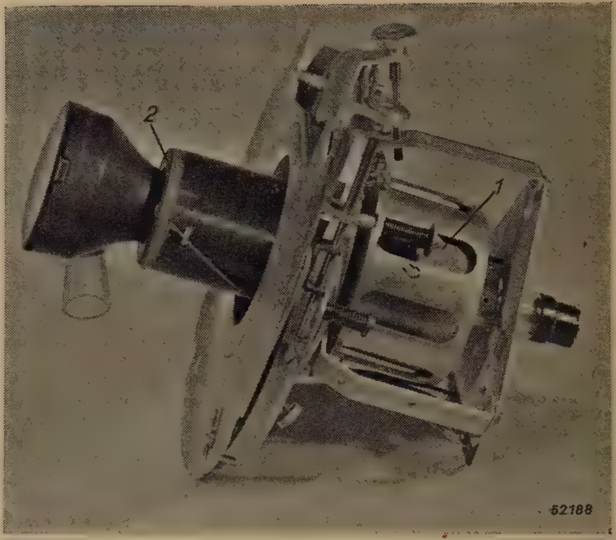

Fig. 17. Cathode-ray tube MW 6-2 placed in the holder with focusing coil (*1*) and deflection coils (*2*).

point *P* and the voltage across the capacitor changes according to an exponential function with the time.

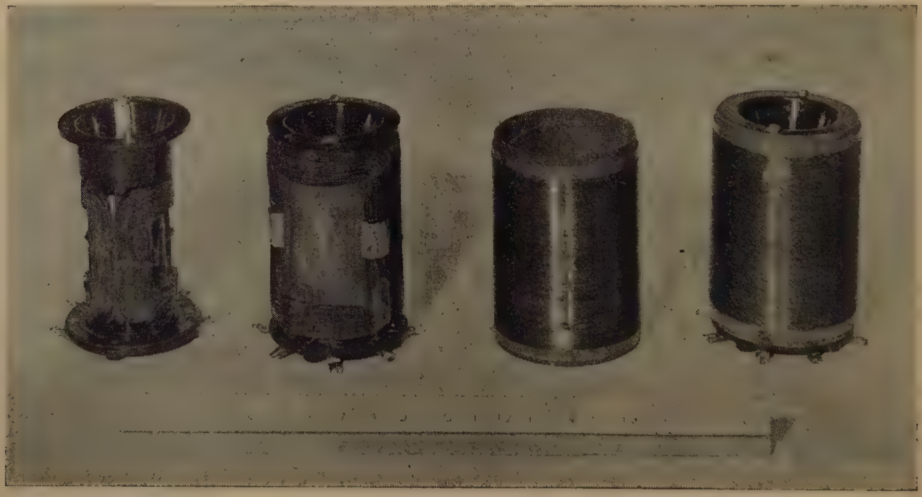

Fig. 16. From left to right: cylinder with one pair of deflection coils, the same with the second pair of deflection coils, envelope wound with iron wire, complete set of deflecting coils.

The oscillator stages

We have seen that a saw-tooth input voltage is required for each of the output stages. These voltages are supplied by relaxation oscillators, viz. blocking oscillators, the working diagram of which is represented in *fig. 18*. In essence such an oscillator consists of a triode with strong positive feedback, a grid capacitor and a grid leak. During oscillation the grid current causes the grid capacitor to be charged to such an extent as to interrupt the oscillation for a certain time, during which period an opposite charge flows across the grid leak to the Owing to the grid leak being connected to a point having a high voltage however, the rate of change of the voltage across the capacitor may to a good approximation be regarded as being linear.

This saw-tooth voltage serves as output voltage of the oscillator stage. Its frequency is adjusted by means of the variable grid leak R_2.

In *fig. 19* we again have a diagram of the blocking oscillator — the one for the vertical scanning — but with the addition of the correcting network (C_1-R_1-C_2). There is an additional resistor R_3 across which the grid current, during its short existence, a voltage pulse is developed which likewise forms part

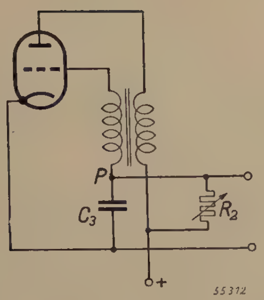

Fig. 18. Diagram of a blocking oscillator. Across the capacitor C_3 a saw-tooth voltage occurs the frequency of which can be adjusted by means of the resistor R_2.

of the output voltage. It has already been shown in the foregoing why these impulses are needed: they have to keep the output valve blocked at the high positive anode voltage arising during the fly-back.

Accurate synchronization with the scanning in the transmitter is assured by the triodes of the oscillator stages, to which at the right moments a pulse is applied which renders the valves conducting just before current would begin to flow naturally. For this purpose, as already stated in the introduction, the triode is coupled to a heptode (fig. 2) controlled by the synchronization signals. We shall revert to this in more detail in a subsequent article.

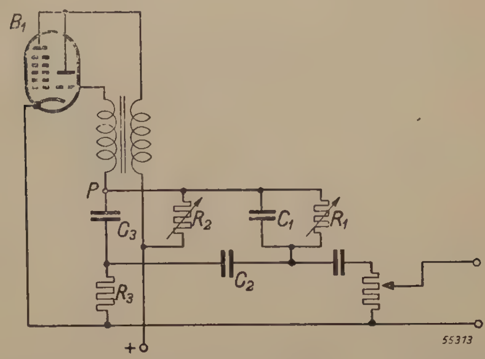

Fig. 19. Diagram of the oscillator stage for vertical deflection, including the compensation network C_1-R_1-C_2. B_1 = heptode-triode, C_3 and R_2 the same as in fig. 18, R_3 = a resistor across which the grid current develops a voltage peak which blocks the output valve during the fly-back.

STORING SEED POTATOES IN ARTIFICIALLY-LIGHTED CELLARS

by R. van der VEEN. 628.978:631.563.8:633.491

Seed potatoes are usually kept in what are known as clamps. They then lose much of their nutriment owing to the formation of long sprouts, which have to be removed. Since light checks sprouting, in may cases glass storage places have been resorted to, but as this method also has its drawbacks a more efficient manner of storing has been sought. This article describes an experiment for storing seed potatoes in an artifically-lighted cellar. It has been found that fluorescent lamps are much better than incandescent lamps for checking sprouting. One would think that this is to be ascribed to destruction of the auxin in the tubers, as it takes place mainly through blue light. A closer investigation into the nature of the active rays showed however that red light has a much stronger checking effect than blue light. These experiments lead one to suppose that, mainly or exclusively through red light, an inhibitor is developed in a potato.

The treatment of seed potatoes

Potatoes intended to be kept for planting out are cropped in the months June, July or August, and then have to be kept eight or nine months before the planting season starts. In order to check as far as possible the loss of nutritive substances through excessive breathing or drying up, soon after being cropped the potatoes are temporarily stored either in clamps or in barns until the autumn, when they are transferred to the winter storage places.

In January or February, and sometimes as early as December, one or more sprouts begin to grow out of each potato. How far these sprouts develop depends upon the kind of potato and the storage conditions, such as temperature, light and humidity. Usually these sprouts are broken off in January, after which the potato begins to sprout anew. If these new sprouts grow too long they, too, have to be removed, and this is disadvantageous for future growth in the field. The best results are obtained with potatoes which at the time of planting have short stubby sprouts and which have only to be "desprouted" once.

Seed potatoes are nowadays an important product of the Netherland's agriculture, which is also of importance for export. It is therefore not surprising that in recent years considerable attention has been paid to the problem of how seed potatoes can best be stored.

It is a known fact that the sprouting of potatoes is particularly checked by cold and by light. A temperature of 2-4 degrees centigrade will stop sprouting even without light, and undoubtedly good seed potatoes would be obtained if they could be kept at that low temperature, but this is not practicable. Neither the growers nor the dealers have storage places which can be kept at a constant temperature of 2-4 °C, independently of the outside temperature. Neither would it be economically justified to store seed potatoes in cold-storage depots, supposing that these were available in sufficient numbers.

At a temperature of 5-9 °C in the dark there is too much sprouting, but with a little light even at that temperature sprouting is sufficiently checked. The application of light, however, is difficult of realization with the present storage places. Until recently all seed potatoes were kept in clamps and even at the present day most of them are stored in this way. So as to profit from the favourable effect of light, in the Netherlands several storage places for seed potatoes have been made of glass in recent years. These are sheds with double walls of frosted glass, and in some of them there is also glass in the roof. In frosty weather the temperature inside these sheds is kept above freezing point by heating; in warm weather they are well ventilated so as to keep the temperature as low as possible. However, it has not been found practicable to keep such a storage place at a constant temperature. The greatest difficulty is in the spring when the weather is fine and sunny, the temperature inside the shed then often rising to 20 °C, which leads to considerable sprouting. Although such a storage place is to be preferred to a clamp, still it does not offer the ideal solution of the problem. The fluctations in temperature, moisture and light are too uncertain factors for the growers and dealers. In severe winters the results are satisfactory but in mild winters the potato develops too many and too long sprouts.

This had induced us to investigate whether better results cannot be reached by storing seed potatoes in cellars and providing artificial light to check sprouting.

The use of artificial light in the storing of seed potatoes

An underground cellar has the advantage that the temperature inside it is practically constant; on comparatively warm winter days the temperature is low and during cold periods it is above freezing point.

In cooperation with Mr. W. H. de Jong of the Central Institute for Agricultural Research (Centraal Instituut voor Landbouwkundig Onderzoek), extensive practical tests were carried out in a cellar of the "Lilbosch" Abbey at Pey-Echt (Limburg). The seed potatoes were stored in the usual way in shallow boxes made with high corners and stacked one on top of the other so as to leave an open space between. When artificial light is employed it is thus able to penetrate between the boxes, though of course where there are dense stacks of them, those farthest away receive only little light.

One part of the test cellar was illuminated with ordinary incandescent lamps and another part with fluorescent lamps of the "daylight" colour. This lighting was started on 3rd January 1948 and left burning continuously up to 31st March, when the potatoes had to be planted out.

In the part illuminated with incandescent lamps there were six 100-W lamps installed in a section 7 × 8 metres. At the end of the test the potatoes kept in this section were in a better condition than those which had been kept in clamps, but even so some difficulties arose.

Fig. 1. A cellar in the "Lilbosch" Abbey at Pey-Echt (Limburg) where seed potatoes are being stored under the light from fluorescent lamps. In each section of 7 × 8 metres there are five TL lamps of 40 W. The boxes are stacked in such a way that the rays of light can penetrate into the farthest corners. It has been found that with this arrangement the sprouting of the potatoes is sufficiently checked.

In the first place it was found that the potatoes in the immediate vicinity of the lamps began to sprout rather strongly, notwithstanding the fact that they were receiving a fair amount of light. This is to be explained by the radiation of heat from the incandescent lamps, the temperature of these potatoes being raised so high that the light was incapable of checking the growth of sprouts.

A second objection is that in incandescent lamps light is radiated from a central point, in consequence of which there is little uniformity in the radiation. There were found to be a number of more or less large spaces where hardly any light could penetrate, as a result of which sprouting was not checked.

In the part of the cellar illuminated with fluorescent lamps five TL lamps of 40 W were installed in each section of 7 × 8 metres, placed at intervals of 3 metres. Since these lamps were mounted vertically against the wall (*fig. 1*) the light was able to penetrate between the boxes, so that as soon as a sprout began to grow it at once came into the light. With the lamps mounted in this way there are no shadow spots.

Fluorescent lamps produce scarcely any heat radiation, so that the potatoes in the immediate vicinity of the lamps do not sprout any earlier than the others and there is no need to rearrange the boxes after a certain time.

Thus the TL lamps yielded much better results than the incandescent lamps. The sprouts which had developed towards the end of March were stubby and tight, so that the potatoes (varieties: "Eersteling" and "Bintje") could quite well be planted mechanically. It was found that with the arrangement chosen, with the stacks extending up to 3-4 metres away from the lamps, even the boxes farthest away still received sufficient light. *Fig. 2* shows potatoes stored in a clamp in comparison with those which had been radiated with fluorescent light.

Unfortunately these experiments at Pye-Echt did not begin until January 3rd and it was necessary in the beginning to break off sprouts that had already formed. If we had been able to start with the irradiation of the potatoes back in November there would most probably have been no need to break off any sprouts. It is intended to repeat this experiment next winter and to see whether it is in fact necessary to keep the lamps alight continuously or whether it is sufficient to switch the lamps on for say 8 to 12 hours per day. The fact that irradiation with TL lamps yielded much better

results than that with incandescent lamps has to be ascribed, in the first place, to the shape of these TL lamps and their smaller heat radiation, though also the spectral composition of the radiated light will

Fig. 2. Comparison between potatoes kept in the clamp (above) and others taken from a cellar illuminated with TL lamps (below). The former have developed long sprouts, in consequence of which the potatoes have lost much of their nutriment. The others have short stubby sprouts making these potatoes most suitable for planting out.

undoubtedly play an important part. It is therefore worth while investigating the kind of light which checks the sprouting of potatoes most. It is moreover of interest to ascertain what amount of light — using light of a certain wavelength — is just capable of sufficiently checking sprouting.

The optimum colour for irradiating potatoes

In order to investigate the effect of the colour of the light used, we irradiated one lot of potatoes with various intensities of blue and another lot with different intensities of red light. For the first lot a TL lamp was used with magnesium tungstate as luminophore and the addition of a blue filter. For the second lot a lamp with cadmium borate was used, with a red filter. The spectral distribution of the light from the two lamps is graphically represented in *fig. 3*. The irradiation took place at a temperature of 14 °C.

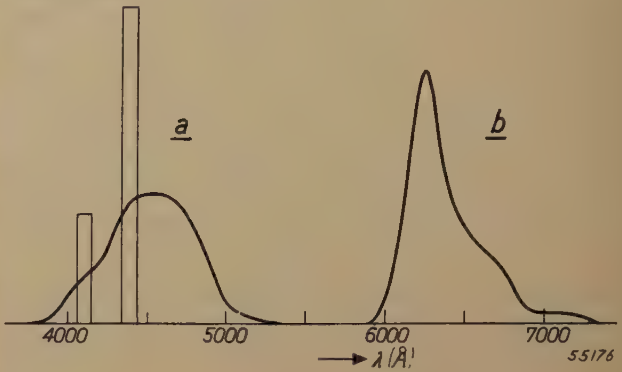

Fig. 3. The spectral distribution of the light from two fluorescent lamps used for the experiments regarding the influence of light rays on the sprouting of potatoes. The two rectangles relate to the light from two mercury lines. The area of these rectangles is a measure for the relative energy contribution of these spectral lines. The part *a* shows the spectral distribution for the TL lamp with blue light, the part *b* that for the TL lamp with red light.

There has been very little research into the mechanism of the sprouting of potatoes and the checking of same. It is known that the growth of the sprouts takes place under the influence of auxin, a hormone occurring in the growing parts of all higher species of plants. It is obvious to presume that the growth will be checked by the destruction of this auxin. It is known that blue-violet light has this effect but that red rays are of little influence.

Even in the smallest concentrations auxin is highly active, $5 \cdot 10^{-11}$ gram giving a measurable reaction in growth. Since such minute quantities cannot be measured chemically, the presence of this substance is determined by means of a quantitative biological analysis, a brief description of which follows.

In the seedlings of oats (Avena) this auxin is formed in the tip and when the tip is cut off the seedling ceases to grow, but if the tip is put back onto it then growth starts again at once. Auxin is mainly transported perpendicularly downwards. When the tip is put back over only part of the decapitated seedling the latter starts growing on one side and not on the other, so that it bends over. This curvature is used as a measure for the amount of auxin present. The unit (called the Avena unit) is the amount of this hormone which produces after 90 minutes in an oat seedling a curvature of 10°. To determine the auxin content of the tissue of a plant the auxin is diffused in a small block of agar which is then placed on a decapitated seedling in such a way as to cover only half of the wound. The curvature resulting after a certain time is used to indicate the number of Avena units of auxin present.

The auxin that is chemically distinguished as auxin-a is photo-stable, that is to say its activity cannot be influenced by irradiation. In weak acid solutions, however, this auxin-a readily changes, accompanied by separation of a molecule of H_2O, into auxin-a-lactone, a substance which is equally active

as a stimulus to growth but which is photo-labile. Under the influence of ultra-violet light this substance changes, not reversibly, into lumi-auxone, again accompanied by separation of a molecule of H_2O, and this substance has no longer a growth-stimulating action. In the absence of ultra-violet irradiation this transformation in the vegetable tissue would not take place if it were not for the fact that in the presence of carotene (invariably found in plant tissues) the reaction also takes place under the influence of rays from the blue-violet part of the visible spectrum. In vitro too it has been found possible to render auxin mixed with carotene inactive by means of small quantities of visible light. It appears that this result is mainly to be ascribed to the light of wavelengths occurring in the absorption spectrum of carotene. In agreement with this is the fact that growth reactions due to light are strongest — if we leave out ultra-violet light — under the influence of blue-violet light (wavelength 4300-4600 Å). The carotene present then causes the partial destruction of the growth stimulus.

expected, the sprout which had been under light of an intensity up to about 30 erg/cm²·sec being perceptibly checked in their growth. All the sprouts, including those which had not been checked at all or scarcely so, were turned more or less to the light owing to the auxin on the exposed side having suffered greater destruction than on the unexposed side. The sprout that had received about 2 erg/cm²·sec was still somewhat phototropically directed; this is also the minimum radiation intensity at which oat seedlings show a curvature under the influence of light.

There was an unexpected phenomenon with the potatoes that had been exposed to red light. In the first place the sprouting of these potatoes too was checked, so much so that it was even noticed

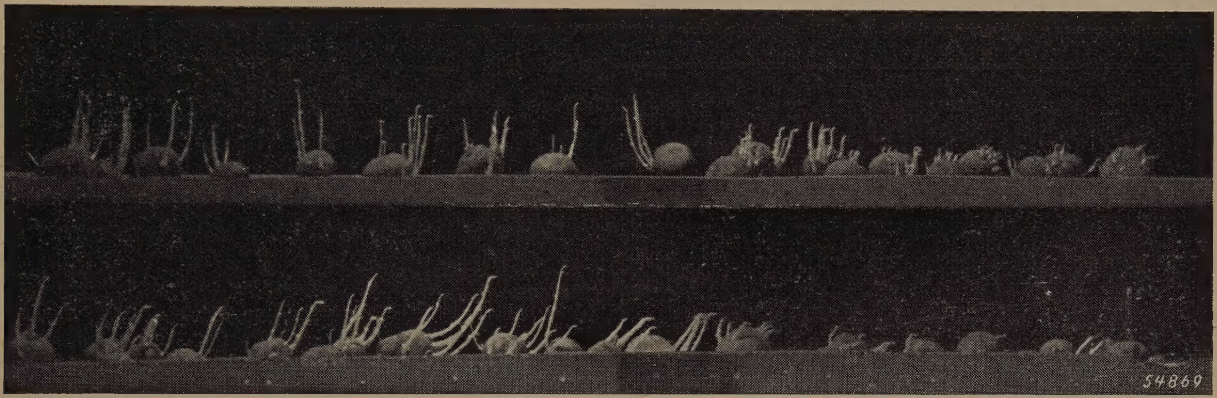

Fig. 4. Potatoes (variety "Eersteling") sprouting at a temperature of 14 °C under irradiation with the two kinds of fluorescent light of the composition represented in fig. 3. The light is incident from the right. The photos have been taken after 3 weeks irradiation. *Above:* irradiation with red light, the intensity diminishing from right to left from 3 to 0.1 erg/cm² · sec. *Below:* irradiation with blue light, the intensity diminishing from right to left from 80 to 2 erg/cm² · sec.

In the light of the results obtained form experiments concerning the destruction of auxin it was to be expected that the growth of the sprouts in seed potatoes would be most strongly checked by blue-violet light and that red rays would have but little effect.

Experiments carried out in cooperation with Prof. E. C. Wassink in the Laboratory for Physiological Research of Plants (Laboratorium voor Plantenphysiologisch Onderzoek) at Wageningen (Holland) were so arranged that the light fell continuously upon the potatoes from one side, as would be the case in the storage of potatoes. Thus, the farther they were away from the lamp the less light fell upon the potatoes. *Fig. 4* shows how the irradiation checks the development of the sprouts.

The results under blue light were in fact as

under a very much lower luminous intensity than with blue light, intensities of 1 erg/cm² · sec producing noticeable results. But what was most surprising was the fact that the checked sprouts

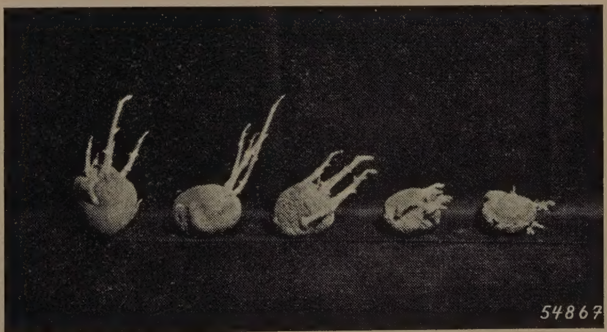

Fig. 5. Potatoes sprouting under blue light incident from the right. The intensities of illumination were, from right to left, respectively 80, 50, 15, 7 and 2 erg/cm² · sec.

under red light had not grown towards the light not even under much stronger radiation.

The phenomena observed under irradiation with the two kinds of light are clearly seen in *figs. 5* and *6*, showing some potatoes taken from the experiment to which fig. 4 relates. One can see what sprouts have grown under blue light and under red light respectively; the legends indicate the intensity with which the potatoes were irradiated.

Fig. 6. Potatoes sprouting under red light incident from the right. The intensities of illumination were, from right to left, respectively 3, 1.5, 0.8, 0.3 and 0.1 erg/cm²·sec.

From these experiments it appears that the checking of sprouting, — at least under the influence of red light — is not to be accounted for by reason of a growth-stimulating substance being rendered inactive by the light. Rather it is to be supposed that, under red light, a growth-checking substance in the potatoes is activated which then, contrary to auxin, would appear to diffuse through the sprouts in a horizontal direction. The result of this would be that instead of growing in the direction of the light they grow vertically upwards, at least in so far as they develop at all. The question whether this hypothesis of the activation of a growth-checking substance is correct is to be further investigated experimentally.

Very little is known in botany about growth-checking substances, although in recent years some substances have been extracted from plants which are found to check growth. For nstance P. Larsen [1]) describes the growth-checking action of parasorbinic acid from tomato juice and of anemonin from Rananculus. No investigations have yet been made into the formation of such substances under the influence of light.

Our experiments now having shown that red light has the strongest checking action upon the sprouting of potatoes, in the further experiments it will be advisable to use TL lamps of the "warm-white" colour instead of those of the "day-light" colour. This should be taken into account when fitting up storage cellars for seed potatoes with artificial light.

[1]) Amer. J. Bot. 34, 349-356, 1947.

ABSTRACTS OF RECENT SCIENTIFIC PUBLICATIONS OF THE N.V. PHILIPS' GLOEILAMPENFABRIEKEN

Reprints of these papers not marked with an asterisk can be obtained free of charge upon application to the Administration of the Research Laboratory, Kastanjelaan, Eindhoven, Netherlands.

1794: F. A. Kröger and J. E. Hellingman: The blue luminescence of zinc sulfide (J. Electrochem. Soc. **93**, 156-171, 1948, No. 5).

It is shown that the ions Cl^-, Br^-, and I^- play an essential part in the formation of the blue centers of ZnS-Ag, ZnS-Zn, and ZnS-Cu phosphors. The centers are assumed to be Zn^+Cl^-, Ag^+Cl^- and Cu^+Cl^-, respectively (or the corresponding bromides and iodides), and to occupy normal zinc and sulfur sites in the zinc sulfide lattice. The spectral distribution of the fluorescence is the same for the centers containing chlorine or bromine ions; Ag, Zn, and Cu cause bands at slightly different wavelengths.

A difference in peak positions for wurtzite and sphalerite is explained by the difference in separation between the upper occupied and the lower empty band of the base lattice.

1795: A. H. W. Aten Jr., C. J. Dippel, K. J. Keuning and J. van Dreven: Denaturation and optical rotation of proteins (J. Colloid Sci. **3**, 65-66, 1948, No. 1).

It is fairly generally admitted that denaturation consists of a loosening of the native configuration of a protein, followed by refolding according to a less regular pattern. This denaturation is sometimes reversible. However, not all characteristics of the native substance are equally well reproduced in the regenerated product. The writers measured the optical rotation of solutions of regenerated seralbumin. No difference was observed, within the accuracy of the experiments (3°), between the rotation of native and regenerated seralbumin.

1796: J. L. Snoek and J. F. Fast: Metastable states of nickel characterized by a high initial permeability (Nature, London, **161**, 887, 1948, June 5).

In textbooks on the subject it is usually tacitly assumed that the initial permeability μ^0 of a ferromagnetic material not subject to ordering, ageing or allotropic transformations, is a unique function of the temperature. In contradiction to this the writers found for Ni that the temperature curve for μ^0, when taken at rising temperatures, differs markedly from the curve obtained at decreasing temperatures. Slightly tapping or demagnetizing the sample brings μ^0 down to values which — though mutually different — are independent of the previous heat treatment.

1797: L. J. Dijkstra and J. L. Snoek: Effect of lattice distortions on the mean rate of propagation of large Barkhausen discontinuities (Nature, London **161**, 886, 1948, June 5).

The experiments of Sixtus and Tonks on the propagation of large Barkhausen discontinuities have been repeated and extended, using slightly more refined methods. The relation $V = A\ (H - H_0)$ between the mean rate of propagation V and the external field H, where A and H_0 are certain constants, is found to be strictly valid in all cases investigated. Experiments on a 60 Ni 40 Fe alloy showed that A is very sensitive to defects in the lattice structure. Experiments at different temperatures (93 °K—368 °K) showed that A/R, where R is the resistance, is practically independent of the temperature.

1798: J. van der Vliet: Investigations on sterols II. Vitamin-D_2 and -D_3 in irradiated sterol from the mussel (Mytilus edulis) (Rec. Trav. chim. Pays-Bas **67**, 246-256, 1948, No. 4).

The following compounds have been detected in the sterol fraction from the mussel after irradiation with ultra-violet light: Vitamin-D_2 and -D_3 and a compound closely related to -D_2 and having a vitamin-D structure, but which is practically devoid of anti-rachitic action. A mixture of this compound with vitamin D_2 has been isolated in a crystalline state (-D_x).

1799: J. van der Vliet: Investigations on sterols III. The provitamins-D from the mussel (Mytilus edulis) (cf. these abstracts, No. **1741**) Rec. Trav. chim. Pays-Bas **67**, 265-281, 1948, No. 5).

In a further investigation on the sterol fraction from the mussel the following degradation products have been obtained by oxidation of the ultra-violet irradiation product: formaldehyde, the well known degradation ketone $C_{18}H_{22}O$ from vitamin-D_3, methyl-isopropyl-acetaldehyde and isopropyl-acetal-

dehyde. The latter aldehydes were detected by conversion into and isolation of the corresponding acid amides.

Qualitative and quantitative consideration of the results compared with similar degradations of calciferol and an irradiation product from 7-dehydrocholesterol, as well as biological data, lead to the conclusion that "mussel provitamin-D" is composed of: 7-dehydrocholesterol (about $^3/_6$ part), ergosterol (about $^1/_6$ part), $\triangle^{5,7,22}$-cholestatriene-3-ol. (between $^1/_6$ and $^2/_6$ part) and 2nd component of provitamin-D_x ($< ^1/_6$ part).

The last two components probably cannot, or at least to a small extent only, be activated antirachitically.

1800: J. M. Stevels: Les propriétés optiques du verre en rapport avec sa structure (Verres et Refractaires 2, 2-12, 1948, No. 1). (The optical properties of glass in relation to its structure; in French.)

The writer recapitulates the well-known rules of Zachariasen regarding the conditions anorganic compounds (chiefly oxydes) should comply with, in order to be able to occur in the form of a glass (see Philips techn. Rev. **8**, 231-236, 1946). Especially the relation between colour and structure of homogeneous glasses is studied. The absorption is shifted to decreasing wavelengths according as the Madelung potential on the place of an oxygen ion increases, e.g. going from borate glasses, via silicate glasses to phosphate glasses. However, certain ions may occur, which have a specific absorption and thus cause a colour of their own. A network-modifying ion as a rule has a narrow absorption band. If the same ion occurs as network former the absorption is much broadened and especially extended to the larger wavelengths. Between both functions of the ion an equilibrium exists, which may be influenced by outer circumstances, e.g. by heat treatment or by admixing special ions, such as Be^{2+}, Ti^{4+}, B^{3+}. In this way the influence of the structure on the specific absorption of Fe^{3+}, Cu^{2+}, Co^{2+}, Ni^{2+}, U^{6+} and Mn^{2+} may be understood. This is extensively discussed in the case of Fe and briefly in the other cases too.

1801: J. de Jonge and R. Dijkstra: Decomposition of o-hydroxydiazonium compounds by light. (Rec. Trav. chim. Pays Bas **67**, 328-342, 1948. No. 6).

Conditions could be found for decomposing a solution of an o-hydroxybenzene-diazonium compound into a colourless product. Such an irradiation product couples with diazonium salts in slightly acidic solution to red-shaded dyes according to a bimolecular reaction. However, it is not stable in solution at room temperature, but is converted slowly into a non-coupling dimeric form. The irradiation of the diazonium salt gives rise to a new, weak acid function that disappears again on heating with evolution of CO_2. Titration curves show that the o-hydroxy-benzene- and o-hydroxynaphthalene-diazonium compounds are decomposed in a similar way. Two irradiation products of o-hydroxynaphthalene diazonium compounds have been isolated. The results are completely understood by assuming the conversion of the benzene-nucleus into a five-membered ring, as recently concluded by Süs from other experiments.

1802*: J. D. Fast: Entropie (Amsterdam, Centen 1948; 270 p., 25 fig., 32 tables) (in Dutch).

The author aims at giving, in as simple terms as possible, a survey of the fundamentals of I) thermodynamics, II) quantum mechanics, and statistical mechanics as far as needed for the illustration of the concept of entropy. Part III deals rather extensively with the calculation of gas entropies from simple molecular models and from spectral data.

1803*: P. Cornelius: Korte samenvatting der electriciteitsleer (Meulenhoff, Amsterdam, 1948; 88 p., 7 fig., 3 tables). (A short survey of the theory of electromagnetism; in Dutch.)

In this booklet the author gives a short survey of the theory of electromagnetism indicating important simplifications. The reader is supposed to be more or less acqainted with the basic notions.

The author mainly aims at stopping discussions on electrical units by introducing the Giorgi system of electrical units in its rationalised form. In this connection, starting from the concept of current and voltage, the current field in a conductor (Ohm's law), the electric field of a capacitor and the magnetic field of a coil are dealt with in much the same way. The author emphasizes that the didactics of electromagnetism should be renewed according to his method of exposition, which is much related to that of R. W. Pohl (compare Philips Techn. Rev. **10**, 79-86, 1948, No. 3).